

20M Sprint Capacity Test, a component of the Wheelchair Sports Performance Test:

A SmartWheel® Technology Field Validation Pilot Study

by

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The purpose of this pilot study was to evaluate the relationships between the *20M Sprint Capacity Test* utilizing *SmartWheel®* technology and other speed evaluation techniques. The goal of the *20M Sprint Capacity Test* is to provide an objective protocol for coaches and players to measure speed, training, and performance growth. All participants ($N = 17$) performed two trials of the *20M Sprint Capacity test* with the *SmartWheel®* placed on each side of a wheelchair, provided by the researcher. Results of this research focus on the potential relationships existing between the variables of push length ($r = .650$), push frequency ($r = .594$), peak force ($r = .540$), and speed performance as measured in meters/second by the *SmartWheel®*. The relationships between classification level of the athletes and speed in meters/second suggested a significant relationship ($r = .859$). Due to the highly correlated relationship between classification level and speed, athlete classification (i.e., class) was partialled out to control for this relationship. When partial correlations were analyzed, push length and speed were no longer significantly correlated ($r = .175, p = .532$). Push frequency and speed (m/s) remained significantly correlated ($r = .573, p = .026$); however, peak force and speed (m/s) also were no longer significantly correlated ($r = .464, p = .081$). Additional research is needed to further validate these results and develop speed training assessment protocols for athletes with disabilities.

20M Sprint Capacity Test, a component of the Wheelchair Sports Performance Test:

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Section I: Manuscript

Introduction

Wheelchair sports background. In its most basic explanation, competitive wheelchair sports consist of three factors: the athlete, the wheelchair, and the interaction between these two elements (Goosey-Tolfrey, 2010). In 1944, Sir Ludwig Guttman introduced sport as rehabilitation for people with spinal cord injuries at Stoke Mandeville Hospital through the request of the British Government (Tawse, Bloom, Sabiston, & Reid, 2012). Thus, wheelchair sports have developed from World War II, post-war rehabilitation programs to elite international competitive events today (Barfield & Malone, 2012). Athletes with a disability, like all athletes, invest considerable time and effort to achieve their best performance goals (De Groot, Balvers, Kouwenhoven, & Janssen, 2012). Part of achieving their best performance is developing the most efficient propulsion techniques.

Objective testing of wheelchair sports performance. Wheelchair sports propulsion techniques and strategies are complex and involve several factors (Goosey-Tolfrey & Kirk, 2003). Identifying the specific aspects of propulsion related to mechanical efficiency is important both theoretically and practically (De Groot, Veeger, Hollander, & Woude, 2002). Intervention strategies to improve athletes' pushing techniques and mechanical efficiency have been a topic of great interest to sports scientists for many years (Goosey-Tolfrey, 2010). Studies in wheelchair sports are essential to optimizing sport performance (Vanlandewijck, Theisen, & Daly, 2001). It is important to further biomechanical and physiological understanding to help determine the optimal benchmarks in efficiency and energy expenditure with regards to

wheelchair design, physical conditioning, physical capabilities, and power output parameters (Van de Woude et al., 1988).

The specific movements and activities used in wheelchair sports have most commonly been measured using a laboratory ergometer, which fails to address the contribution of forward momentum of the wheelchair brought by the movement of trunk and upper body (Moss, Fowler, & Goosey-Tolfrey, 2005). Field testing, rather than traditional laboratory testing, is a more feasible way to get an indication of performance standards (De Groot et al., 2012). Improvement in testing outside of the restricted lab environment has been advanced through the use of telemetry-based velocometers, enabling researchers to measure wheelchair push velocity in a more realistic environment (Moss, Fowler, & Tolfrey, 2003). Despite the major improvement in general technology, wheelchair propulsion technique is still not very well understood (Van der Woude, Veegar, Dallmeijer, Janssen, & Rozendaal, 2001). There is a need for standardization and consensus for applied measurement strategies, technologies, and methodology in the field of disabled sports (Van der Woude et al., 2001).

To collect reliable test results, sport-specific testing methods are needed for athletes who participate in sports that require the use of a wheelchair (Muller, Odermatt, & Perret, 2004). Some performance-based movements involved in specific wheelchair sports such as basketball and rugby include: starting, sprinting, braking, and turning (Goosey-Tolfrey & Moss, 2005).

Wheelchair sports performance measurement. Research with ergometers and other tools has not been practical for clinical usage (Cowan et al., 2008). A limited number of groups have the availability of the required equipment technology necessary to further analyze propulsion techniques (Van der Woude, Bakker, Elkhuisen, Veeger, & Gwinn, 1998; Woude, Baker, Elkhuisen, Veegar, & Gwinn, 1998). One such device, the *SmartWheel®*, can be used to

study force generation strategies under sport-specific conditions, as well as in generalized clinical settings to address the different components of the movement dynamics of manual wheelchair users such as: starting, wheeling, braking, and turning (Vanlandewijck et al., 2001). The impact of these sport-specific movement dynamics, such as backward pulling in wheelchair rugby, have been recommended for more complex analyses utilizing three-dimensional modeling, which is provided by the *SmartWheel®* technology (Vanlandewijck et al., 2001).

The *SmartWheel®* and wheelchair sports. Three Rivers Holdings, LLC, developed The *SmartWheel®* as a technological device that analyzes various output measures of manual wheelchair usage. The original prototype of the *SmartWheel®* was meant to help health practitioners better understand the physiological and physical effects of wheelchair propulsion on the body (Cooper, 2009). Prior to this invention, little information was known with regard to the newly developed field of studying wheelchair propulsion biomechanics (Cooper, 2009). In 2009, seven of the top ten rehabilitation hospitals in the United States used the *SmartWheel®* device for clinical and research purposes (US News & World Report Rankings, 2009). The *SmartWheel®* utilizes wireless computer technology to visually display push forces, push frequency, push length, push smoothness, and speed among manual wheelchair users. This has allowed recreational therapists and other allied health professionals the ability to analyze *SmartWheel®* reports to optimize rehabilitation for patients with spinal cord injuries. The *SmartWheel®* collected output data can also be compared against a national database (N=990) (Three Rivers Holdings, 2008).

In addition to its clinical rehabilitation application, *SmartWheel®* has been utilized to assist in the design of accessible pedestrian walkways, accessible playground surfaces, and to evaluate various types of surfaces, such as carpet, for wheelchair accessibility (Cooper, 2009).

These other applications of the *SmartWheel®* have grown as new applications in the field of wheelchair biomechanics and subsequently advanced service delivery have advanced (Cooper, 2009). The combined development of the *Wheelchair Sports Performance Test* (Loy & Brown-Bochicchio, 2011) and the measurement application of *SmartWheel®* were intended to contribute to the applied use of the device.

The *SmartWheel®* offers a way to collect advanced data using three-dimensional software to assist in improving performance for wheelchair athletes. In a simple testing session, the *SmartWheel®* replaces one of the wheels on a standardized 24-inch wheelchair rim. Throughout the duration of the performance testing, a laptop computer visually displays the output measures of the push propulsion and performance elements of: total elapsed time of the session, distance traveled during the session, average speed, highest speed, number of pushes measured during the testing period, peak force, peak backward force, off-rim acceleration, speed/push frequency ratio, push length, push frequency, peak/average force ratio, average push force, and push mechanical effectiveness percentage (Three Rivers Holdings, 2008). After analyzing these data measures, interventions can then be utilized to optimize propulsion elements for injury prevention, sports performance optimization, and third party reimbursement to justify specific wheelchair upgrades (Three Rivers Holdings, 2008). Some researchers have suggested field-based assessment methods take into consideration game-play scenarios that would be advantageous to wheelchair athletes (Goosey, 2010). This study is unique in that the *SmartWheel®* provides field-based data collected in an applied setting.

Development of a performance assessment tool. Several assessment tools, such as the *Wheelchair Users Functional Assessment* (WUFA©), have been developed to assess disability levels of wheelchair users (Stanley, Stafford, Rash, & Rodgers, 2003). This particular test was

created because a functional outcome tool that included daily activities necessary for independence simply did not exist (Stanley et al., 2003). While assessment tools such as the WUFA© provide performance-based assessments, they do not assess the range of elements of a wheelchair push that the *SmartWheel®* collects.

Utilizing the *SmartWheel®* in applied settings with wheelchair athletes offers several benefits to athletes, coaches, practitioners and others with interest in practical applications of wheelchair usage. *SmartWheel®* provides unprecedented measurable data to wheelchair athletes, as well as non-athletes, who have never before been able to correlate the amount of effort they exert during specific movements to objectively measured data. Examining these propulsion movements in an applied setting allows for measurements to be taken in real world scenarios and environmental surroundings used by manual wheelchair users after discharge from acute rehabilitation facilities. This applied research setting offers a unique environment in contrast to the common clinical rehabilitation setting.

Disabled sports provide a setting that may provide the *SmartWheel®* a unique non-clinical application. Adding quantitative data to the traditional methods of classifying athletes, for example, may lead to a more evidence-based system of this process of classification (Sarro, Misuta, Malone, Burkett, & Barros, 2010). *SmartWheel®* fits many personal wheelchairs so measurements are accurate to everyday life. This contrasts a traditional clinical testing in which wheelchair users must use pre-determined, non-customized wheelchairs for testing. Other more commonly used reasons to utilize *SmartWheel®* technology include evaluating wheelchair set-up and push style to reduce repetitive stress and to assist in equipment selection and insurance justification for reimbursement (Three Rivers Holdings, 2008).

To fully examine the performance of wheelchair athletes, measurements of players should include an assessment of aerobic capacity, anaerobic capacity, and specific wheelchair sports-related skills (Vanlandewijck, Daly, & Theisen, 1999). As an additional performance indicator, baseline measurements of athletic performance indicate the weak and strong points of an athlete (De Groot, Balvers, Kouwenhoven, & Janssen, 2012). The *SmartWheel®* can provide the instrumentation needed to assess wheelchair sports-related skills by providing a portable, adaptable instrument to collect real-time performance data during each push on the wheelchair handrim (Three Rivers Holdings, 2008).

The *Wheelchair Sports Performance Test (WSPT)* (Loy & Brown-Bochicchio, 2011) is comprised of a set of five tests used to objectively measure the performance of wheelchair athletes through the utilization of the *SmartWheel®*. These include: the 20M Sprint Capacity Test, Sprint Dribble Capacity Test, Backward Push Efficiency Test, Figure-8 Ball Test, and Shuttle Push Test. See Appendix A for 20M Sprint Capacity Test. Due to the breadth of components which comprise the larger *WSPT*, this study only examined and analyzed the *WSPT* component of speed, as measured by the 20M Sprint Capacity Test.

The most appropriate manner to evaluate a specific wheelchair skill is a set of field tests, enabling trainers and coaches to measure individual progress and level of achievement in their sport specific applied setting (Vanlandewijck et al., 1999). Currently, there is little literature on disabled sports and even less on training programs for disabled sport athletes (Gulick, Berge, Borger, Edwards, & Rigterink, 2006). Abel, Peters and Platen (2003) further asserted that an increase in disabled sports performance-specific information would contribute to developing more effective training programs for athletes participating in disabled sports. The *WSPT* aims to

provide coaches with an objective measurement tool to address disabled sports training related to speed and standardized speed assessment techniques.

Purpose statement. The purpose of this research was to serve as a pilot study to evaluate the relationships of the *20M Sprint Capacity Test* utilizing *SmartWheel®* technology with commonly used speed evaluation techniques. The *20M Sprint Capacity Test* records real time athletic performance measures with the intention of providing wheelchair sports teams with a valid protocol to utilize on an ongoing basis. To test the validity of the *20M Sprint Capacity Test*, athlete performance results were compared to two types of coaches' ratings of players, as well as to speed performance results, using a traditional stopwatch. Demographic factors related to performance on the *20M Sprint Capacity Test* were collected to examine relationships between performance outcomes and demographic data. The demographic factors included: (a) athlete's current classification level, (b) years of previous athletic experience prior to the onset of the disability, (c) years of experience playing a particular sport after the onset of disability, (d) hours of practice per week for a particular sport during the sport season, and (e) age of athlete.

The goal of the *20M Sprint Capacity Test* is to challenge athletes to a greater level of performance by providing coaches and athletes with an objective protocol to measure speed and performance growth. Like many other sports, these measures are intended to motivate athletes to push themselves to improve performance and to provide coaches with a skill-based test to assess and evaluate athletes.

Methods

This pilot study investigated speed and speed-related variables of athletic performance on the *20M Sprint Capacity test* in an applied, community setting. The researcher employed a convenience sampling method and utilized data collected at teams' regularly scheduled practice

times and practice facilities. This study was approved by East Carolina University's University & Medical Center Institutional Review Board (See Appendix B).

Sample population. Participants for this study were recruited through a local chapter of the National Spinal Cord Injury Association as well as from team contacts from the United States Quad Rugby Association (USQRA) and the National Wheelchair Basketball Association (NWBA). Utilizing these resources, a total of ten teams, approximately 100 players, and one regional tournament director were contacted as potential participants in this study. Four coaches replied to the researcher's inquiry, volunteering their teams. From those four teams, seventeen athletes agreed to participate. Fifteen participants were male and two were female. All four teams were located in cities in the southeastern part of the United States. Nine participants were members of wheelchair rugby teams and the other eight participants played on wheelchair basketball teams. Demographics of the participants are in Table 1.

Table 1

Demographic Data of Wheelchair Athletes

Participant	Modified Classification	Yrs Prior	Yrs Post	Practice Hrs/week	Age	Gender
BB001	3.5	11	11	3	38	M
BB002	3.5	11	9	3	30	M
BB003	5.5	0	11	3	21	M
BB004	4.5	0	11	5	31	M
BB005	5.5	11	11	7	53	M
BB006	4.5	7	11	5	46	M
BB007	5.5	11	11	6	43	M
BB008	3.5	4	6	3	39	M
QR001	2.5	11	6	3	32	M
QR002	3.0	5	6	9	52	M
QR003*	0.5	11	2	3	27	F
QR004	1.0	5	0	3	23	M
QR005	0.5	2	3	7	21	M
QR006	3.0	7	11	3	41	M
QR007	2.0	11	11	11	37	M
QR008	1.5	11	11	3	60	M
QR009	-	0	2	3	27	F
Mean:	3.15	6.94	7.82	4.65	36.53	
SD	1.68	4.45	3.98	2.47	11.62	

Note. *= Personal wheelchair was used during assessment. BB = Basketball, QR = Quad Rugby; Yrs Prior = Years of athletic experience prior to the onset of disability; Yrs Post = Years of athletic experience after the onset of disability; Yrs Prior and Yrs Post =11 (>10 years of experience); M=Male; F=Female

All participants in this study utilized a sports wheelchair in competition. Due to the limitations of having access to only one 24-inch *SmartWheel®*, participants in this study were tested in a standardized wheelchair provided by the researchers fitted with a 24-inch wheel size. This standardization was implemented to remove individual performance influences based on custom wheelchair configuration (Van de Woude et al., 1998). However, if the athlete needed a 24-inch wheel, to accommodate his or her particular functional needs, then the athlete was assessed using his or her own wheelchair. One participant's wheelchair used a 24-inch wheel, allowing the athlete to use a personal wheelchair for assessment and also provided additional

support due to the athlete's level of injury. All other participants used the same sport wheelchair provided by the researcher.

Wheelchair Sports Performance Test Protocol

After reviewing major wheelchair sports skills tests (Brasile, 1986; Brasile, 1990; Vanlanddewijck et al., 1999; Goosey-Tolfrey & Tolrey, 2008), it was evident that the major components of both wheelchair basketball and wheelchair rugby are speed, agility, stopping speed, and ball handling. The *Wheelchair Sports Performance Test* (WSPT) consists of five specific skills test items that have been adapted in part from other similar skills tests (Brasile, 1986; Barfield & Malone, 2012). These tests were used as the basis of the *WSPT*. The addition of the objective ability to measure these skills has been provided by the previously discussed *SmartWheel®* technology. This study only examined the *20M Sprint Capacity Test* of the *WSPT*. The *20M Sprint Capacity Test* was chosen due to the component of speed being a consistent factor in overall athletic performance across many sports. The analysis of the data collected focused on providing evidence of validity for the *20M Sprint Capacity Test*.

20M Sprint Capacity Test Protocol

The *20M Sprint Capacity Test* provides coaches and players with data related to the athlete's speed and factors related to his or her performance and push efficiency. The ability of an athlete to perform a sprint over a distance of 20 meters is a task routinely used to test ability (Doyle et al., 2004). This test has sport specific applications in its ability to indicate an athlete's capability to breakaway to score, accelerate to defend an opponent, or beat an opposing athlete to a particular position on the court (Loy & Brown-Bochicchio, 2011).

The *20M Sprint Capacity Test* protocol was adapted from the field performance tests as suggested by Brasile (1986, 1990) and Vanlandewijck et al. (1995). The protocol for this test

calls for the player to take a position with the axle of the rear wheel aligned with the start line (Doyle et al., 2004). Goosey-Tolfrey (2005) similarly analyzed propulsion over a 20M distance from a stationary start within a population of wheelchair tennis players, using a velocometer as the measurement device. De Groot et al. (2012) also utilized a 20M distance test with the addition of adhering to the IWBF rules for dribbling a basketball. This was part of a larger battery of tests related to wheelchair basketball athletic performance.

In addition to the singular element of measuring speed, the *SmartWheel*® measures data points that support and contribute to the component of speed. These additional data measures include the peak average force ratio, peak push force, push length, and speed/push frequency ratio (Loy & Brown-Bochicchio, 2011). *Peak average force ratio* is the averaged ratio between the peak force during steady-state pushes and the average force exerted during a push (Three Rivers Holdings LLC, 2005). *Peak push force* is defined as the average peak force of all pushes after the initial three pushes (Three Rivers Holdings LLC, 2005). *Push length* is the average length of the individual's push and is measured in degrees (Three Rivers Holdings LLC, 2005). The speed/push-frequency ratio is the average steady-state speed divided by the average steady-state push frequency. These data provide an indication of how many pushes per second an individual exerts to achieve the desired average speed (Three Rivers Holdings LLC, 2005). See Appendix C for specific details of the measurements.

Each participant's data collection session began following the starting commands of, "ready, set, go" and a start signal, which notified the athlete to begin. The athlete attempted to cover the 20M distance as quickly as possible, focusing solely on speed. Each athlete was measured two times with the *SmartWheel*®. One measure was taken on the left side and one measure was taken on the right side in order to accommodate the weight added by the heavier

SmartWheel®. *SmartWheel®* placement on the right and left side of the wheelchair was randomized. During each attempt the athlete's speed was measured by the *SmartWheel®* as well as by a stopwatch operated by the researcher.

Coach ratings. Coach rating evaluation forms were completed for each player by the team's coach using two different rating methods (see Appendix D). The first type utilized a seven point Likert-type scale that asked coaches to rate players on a scale from one to seven based on the coach's subjective opinion of the athlete's overall speed performance. The levels on this Likert-type scale ranged from a rating of one being "Very Slow" (one of the slowest athletes on the team), a rating of four being "Moderately Fast," to a rating of seven being "Very Fast" (one of the fastest on the team). The second rating method used was a Visual Analog Scale (VAS) that asked coaches to make a vertical pen mark along the continuum. This mark indicated the point along the continuum in which they felt correlated with that particular player's speed. The VAS measured 11 centimeters in length and was anchored with a starting point of "extremely slow" and an ending point of "extremely fast." The distance in centimeters from the "extremely slow" anchor to the vertical pen mark was measured as an indication of the player's speed. The purpose for using two types of coach rating scales was that the first scale was a numerical, interval Likert-type scale and provided a different form of rating than the VAS rating. This type of rating was not scaled in interval numbers but rather depended on the coach's subjective visual rating method. These two different types of scales were selected by the researcher due to the difference in assessment methods and were later correlated with athlete's measured speed to validate their use.

Timed assessment. During each test, the researcher timed the athlete using a traditional stopwatch and recorded the time for each trial. The stopwatch was chosen as the standardized method of timed assessment as it is a common device to measure an athlete's speed and is generally used by coaches.

Demographic variables. The demographic variables selected to analyze in this study were based on the researcher's logical inference that these demographic variables may influence athlete's speed performance on the *20M Sprint Capacity Test*. A review of literature also pointed to the influence the selected variables may have on speed-related performance. The advantage that experts of a particular sport or game have may be attributed to both the storehouse of information that an athlete retains and the years of experience the individual has accumulated during his or her involvement (Starkes & Ericcson, 2003). The demographic variables of (a) years of athletic experience prior to the onset of the disability and (b) years of experience playing the particular sport the athlete played after the onset of the disability were the two variables that accounted for this influence of experience prior to and after the onset of a disability. Regarding the demographic variable of hours of practice per week, Baker and Cote (2003) noted that hours of practice serve as the essential base for top levels of performance, especially in team sports involving ball movement. Age of the athlete was selected as a demographic variable due to the researcher's knowledge of the human growth and development process. Thus, the researcher logically concluded that age may possibly influence athletic performance, especially pertaining to high intensity activities such as speed propulsion of a wheelchair as examined in this study. Classification was included as a demographic variable to provide a level of fair competition across individuals with similar degrees of disability by

associating a particular numerical category to an athlete based on several classification factors (Vanlandewijck et al., 1995).

Classification. Each athlete provided his or her current classification score respective to his or her specific sport (rugby or basketball). In general, both classification systems for wheelchair rugby and wheelchair basketball players focus on both the nature and severity of the athlete's disability, as well as on the athlete's functional ability to perform skills associated with the sport (Goosey-Tolfrey & Moss, 2005). The classification process can best be described as a form of medical and/or functional evaluation to place athletes with disabilities in groups that contribute to the most appropriate level of competition (Doyle et al., 2004). Athlete classifications by the International Wheelchair Basketball Federation (IWBF) and International Wheelchair Rugby Federation (IWRf) are based on a player's physical ability to complete fundamental tasks, taking into consideration his or her level of disability (IWBF, 2010; IWRf, 2011). For each of these tasks, the speed with which the protocol is completed often is related to the player's physical impairment, as indicated by his or her classification level.

Basketball players are classified within a scoring range of one (1), a player with the least function, through four point five (4.5), a player with the most function (IWBF, 2010). This classification is based on the player's physical capacity to execute fundamental basketball movements such as: pushing the wheelchair, dribbling, shooting, passing, catching, rebounding, and contact reaction skills (IWBF, 2010). The main factors that determine a player's classification are: trunk function, lower limb function, upper limb function, and hand function (IWBF, 2010). At any point during a basketball game, the team combined classification points may not exceed 14 (IWBF, 2010). By having this classification system in place, the IWBF

equalizes each team's functional potential and helps to ensure that the outcomes of the games are directly related to the athletic abilities and skills of players (IWBF, 2010).

Wheelchair rugby has similar, but different skills under which players are classified. There are seven classes of wheelchair rugby players, ranging from a zero point five (0.5) classification to three point five (3.5) classification (IWRF, 2011). Similar to the wheelchair basketball classification system, a 0.5 classification includes athletes with the least function and players with a 3.5 classification are categorized as having the most function or “minimal” impairment (IWRF, 2011). At any given time during a game, the total number of classification points on the court may not exceed eight points (IWRF, 2011). Wheelchair rugby players must also meet eligibility criteria to play the sport. Limitations in the trunk and all four extremities must be present to be eligible to play wheelchair rugby (IWRF, 2011). Unlike wheelchair basketball in which classification level does not usually define a player's role on the team, wheelchair rugby players within classifications typically have particular roles on the court (IWRF, 2011). A player with a 0.5 classification is usually a blocker, creating traps or blocks for opponents inhibit ball passing and movement down the court (IWRF, 2011). As classification levels increase, the role of ball handling skills required usually increases as well. A player with a 3.5 classification is often the playmaker on the team and has excellent ball handling skills (IWRF, 2011).

For the purposes of this study, a modified combined classification system was established by the researcher so that players from both sports, wheelchair basketball and wheelchair rugby, would be evaluated along the same functional classification interval scale. Ideally, players from each sport could be compared against their sport specific classification level. However, due to the limitation of a small sample size within this study, a modified scale was created so that

players from both sports could be included in one combined classification system permitting the same analysis. This modified scale was created by the researcher of this study and is based on consultations from two experienced coaches of both sports. This combining of scales allowed the functional abilities of both quadriplegia and paraplegia (or similar functional diagnoses) to be classified on one continuous interval scale. The traditional quad rugby scale remained the same until the 3.5 level of classification at which time the level becomes equivalent to a basketball classification of level 1. This is due to the variance in players; whereas, for example, some high classification quad rugby players (level 3.5) may have the same functional classification as a wheelchair basketball classified player (level 1.0). This point of crossover at the 3.5 quad rugby and 1.0 wheelchair basketball level was chosen as these two levels require similar levels of wheelchair skills and trunk control. A level 3.5 classified quad rugby player typically has some trunk control as compared to lower classified players and is expected to be able to use his or her trunk for both chair and ball handling skills (IWRF, 2011). A 1.0 wheelchair basketball player typically has trunk control on a forward plane but does not have as much trunk rotation potential as other higher classified wheelchair basketball players typically do (IWBF, 2010). The modified scale used in this study ranges from a 0.5 to a 7 classification, which incorporates both wheelchair rugby and basketball, and their approximate associated classification levels. This scale is presented in Table 2.

Table 2

Modified Sport Classification Scale

Sport Name	Traditional Classification	Modified Classification
Quad Rugby	0.5	0.5
Quad Rugby	1	1
Quad Rugby	1.5	1.5
Quad Rugby	2	2
Quad Rugby	2.5	2.5
Quad Rugby	3	3
Quad Rugby	3.5	3.5
Wheelchair Basketball	1	3.5
Wheelchair Basketball	2	4.5
Wheelchair Basketball	3	5.5
Wheelchair Basketball	4	6.5
Wheelchair Basketball	4.5	7

Research Questions

The intent of the *20M Sprint Capacity Test* is to provide coaches with an objective measurement tool to evaluate an athlete's performance abilities relating to speed and to provide coaches with a well-developed practice protocol to use during training and evaluation of their athlete's speed. The research questions of this study were:

- 1) What are the relationships between push techniques as measured by push length in degrees, push frequency, peak/average force ratio, and peak force and performance on the *20M Sprint Capacity Test* as measured in meters/second by the *SmartWheel®*?

- 2) What are the relationships between the *20M Sprint Capacity Test* and commonly used methods (coaches' ratings, functional classification, and stopwatch assessment) for assessing speed in disabled sports performance?
- 3) What are the relationships between demographic variables (influence of classification level, previous years of athletic experience prior to disability, years of experience playing the sport post-onset of disability, hours of practice per week, and age of athlete) and speed performance on the *20M Sprint Capacity Test* as measured in meters per second?

Data Collection Procedures

Athletes ($N = 17$) were assessed on the *20M Sprint Capacity Test* twice. One trial was completed with the *SmartWheel®* placed on the right side of the athlete's wheelchair and the other trial was completed with the *SmartWheel®* placed on the left side of the athlete's wheelchair. The purpose of alternating sides of the *SmartWheel®* placement was to remove any potential effect of the unequal amount of weight created by utilizing the *SmartWheel®* during testing. The *SmartWheel®* weighs approximately 12 pounds and has a unique handrim, with which the athlete may have not been familiar. Each athlete took practice runs prior to testing to provide increased familiarity with the push rims. By alternating the sides on which the *SmartWheel®* was placed, an average measurement was created to accommodate for the unique qualities of the *SmartWheel®*. In addition, demographic data including classification level, previous years of athletic experience prior to onset of disability, years of experience playing the sport post-onset of disability, hours of practice per week, and age of athlete were collected prior to the performance testing period (see Appendix E). Prior to the start of data collection the coaches of all teams provided their support of this research project. In addition, all athletes and

coaches taking part in this study were over the age of 18 years and signed an informed consent form (see Appendix F) prior to participation.

Data used for analysis in this study were collected and wirelessly transmitted from the *SmartWheel*® to a laptop specifically assigned for usage with the *SmartWheel*®. The transmitted data were collected for later review on the laptop. Protocols for each test are provided in Appendix A.

Data analysis. The data analysis utilized SPSS version 19 and procedures were based on a review of similar wheelchair sports performance-based tests (Brasile, 1986; 1990; Goosey-Tolfrey & Tolrey, 2008; Vanlandewijck et al., 1999). While understanding that a smaller sample ($N = 17$) violated the recommended sample size minimum of 30, this was a pilot study that intended to explore methods for a more comprehensive examination of the *WSPT*. Therefore, an examination of scatter plots and correlations were determined to be the best tests of a linear relationship for this exploratory study. Due to the small sample size of this study, scatter plots, means, standard deviations (Table 3), and a variable correlation matrix (Table 4) were examined prior to completing further analysis of the research questions. Further analysis related to the preliminary data analysis follows for each specific research question. Following the review of these preliminary analyses, Pearson correlations were examined to address the research questions as well as additional scatter plot analysis for the variables of coach ratings and measured speed to complete analysis of the second research question. Adopting correlations with fewer than 30 participants has been noted in a review of similar disabled sport performance research studies that also had a small sample size of less than 30 participants (e.g., De Groot et al., 2004; Goosey & Campbell, 1998; Goosey-Tolfrey & Moss, 2005; Singla, 2009; Sarro et al., 2010). These previous studies provide a precedence to use correlation analysis for this study.

A simple effect size interpretation (r) was reviewed based on procedures similar to other wheelchair performance studies (Boninger et al., 1999; Goosey-Tolfrey & Moss, 2005). The effect size interpretations for all outcome variables are listed in Table 4. Effect size interpretations for research questions are listed in Tables 5, 6, and 7. The correlation coefficient was used to examine effect size as this measured the linear association between two continuous variables (Cooper & Hedges, 1994; Nandy, 2012). Recommendations in the field of allied health supported a simple interpretation of correlations when reporting effect size (Nandy, 2012; Watkins, 2013). Effect size was used to determine the strength of any existing relationships among speed performance (m/s) and independent variables. Estimating and interpreting effect size of the independent variables is critical as it provides researchers with information regarding the strength of relationships of variables and helps to determine the importance of the results (Watkins, Rivers, Rowell, Green, & Rivers, 2006).

The first research question examined the relationships among total time as measured by the *SmartWheel*® in meters per second and the speed-related measures of push length, push frequency, peak/average force ratio, and the peak force mean. Pearson correlations were calculated to determine the relationships among these performance factors and the participants' speeds. Following a review of other wheelchair biomechanics studies (Chow et al., 2000; Goosey-Tolfrey & Moss, 2005; Van de Woude et al., 2001), it was anticipated that the elements of push frequency and peak force would be highly, positively correlated with speed performance.

The second research question examined the relationships among the *20M Sprint Capacity Test* and commonly used methods for assessing speed. To test this, Pearson correlations were calculated between the *SmartWheel*® measured time in meters per second, a simple stopwatch assessment, and the functional classification of the athlete. The relationship between the

variables of coaches' ratings, using a VAS Scale and a Likert-type scale, and performance on the *20M Sprint Capacity Test* was visually examined using a simple scatter plot. The VAS Scale and the Likert-type scale correlations were analyzed using the scatter plot as coaches from the basketball teams rated players only within the sport of basketball on their particular team and coaches from the rugby team rated players only within the sport of rugby on their particular team. For these purposes, the ratings of both sports, basketball and rugby, were not combined as these two sports are different and coaches perception of players' speed relates exclusively to their team and the sport they coached. It was predicted that the variables between performance outcomes, coaches' ratings of speed, the stopwatch assessment, and functional classification of the athlete would be highly correlated. It was assumed that players with more upper body function (i.e., individuals with paraplegia) would be faster, and perceived as fast as measured by the subjective coach ratings. In addition, the speed measured with the stopwatch should be highly correlated with the speed as measured by the *SmartWheel®*. The correlation coefficients were then reviewed to determine the potential effect size of these variables.

To address the third research question, which examined the influence of demographic variables on players' *20M Sprint Capacity Test* results, Pearson correlations were used to examine the relationships among the functional classification level of the athletes, previous years of athletic experience prior to onset of disability, years of experience playing the sport post-onset of disability, hours of practice per week, age, and performance results on the *20M Sprint Capacity Test*. It was hypothesized that high correlations would exist among performance of the *20M Sprint Capacity Test*, classification level, and hours of practice per week. Correlations were also expected to be high among performance on the *20M Sprint Capacity Test* and age, years of experience playing the sport post-onset of disability, and previous years of athletic experience

prior to onset of disability. The correlation coefficients were then examined to detect the strength of the effect of any significant variables.

Results

Research findings in this study are the results of data collection and analysis of participant demographic data, coaches' ratings of athletes, a traditional stopwatch measurement of speed, and the athletes' measured performance on the *20M Sprint Capacity Test* by the *SmartWheel®*. Table 3 presents the means and standard deviations for the *20M Sprint Capacity Test* performance-related outcome variables. To provide a conservative approach to the small sample size, all relevant scatter plots between speed and measured speed-related variables (e.g., push length, push frequency, peak/average force ratio, and the peak force mean) were reviewed during preliminary data analysis to examine the distribution of data and potential influence outliers may have had on existing standard deviations (Cooper & Hedges, 1994). One data point relating to the relationship between push frequency and speed was further analyzed as a visual review of the scatter plots indicated this point as a potential outlier. This participant was identified as participant QR004. This athlete's push frequency equaled 2.65 pushes per second while the mean of all participants' push frequency was 1.84 pushes per second (Table 3). This athlete's speed was 3.25 m/s while the mean of all participants' measured speed was 2.95 m/s (Table 3). Due to the scatter plot indication that participant QR004 may have been an outlier, QR004 was removed from analysis and correlations were reexamined. Although correlations changed following removing this outlier, [removal of outlier ($r = .653, p < .001$) and including outlier ($r = .594, p = .012$)], no statistical significance changed among this correlation. Demographic data are presented in Table 1 and were used in analysis for research question three. Table 4 displays the overall outcome variable correlation matrix. Given the strong correlation

between athlete classification level and measured speed in meters/second ($r = .873, p < .001$), it was determined that effect of classification level should be removed from the relationships by calculating partial correlation coefficients that controlled for such relationships.

As previously noted, *SmartWheel®* placement of the wheel on the right side or left side of the wheelchair for each of the two trials was randomized across participants. To examine whether or not the placement of the wheel on a particular side would have an effect on a participant's speed, correlations were examined between speed when placed on the right side and speed when placed on the left side. Speed with the wheel on the left and on the right was highly correlated ($r = .959, p < .001$). The mean speed with the *SmartWheel®* on the right side was 2.99 m/s with a SD = 0.74. The mean speed with the *SmartWheel®* on the left side was 2.91 m/s with a SD = 0.78. These significant correlations between the two trials (right vs. left) provided further evidence of the data collection protocols for accommodating any differences between the placement of the *SmartWheel®* measurement device on a particular side of the wheelchair.

Tables 3 - 7 present findings addressing aspects of each research question.

Table 3

20M Sprint Capacity Test Performance Related Outcome Variables

	Likert Scale Rating (1-7)	VAS Scale Rating[cm]	Stopwatch Speed (s)	Speed (m/s)	Push Frequency	Peak/Force Ratio [N]	Peak Force [N]	Push Length [deg]
Minimum	3.0	2.4	6.5	1.8	1.0	1.1	40.0	51.6
Maximum	7.0	11.0	13.2	3.9	2.6	2.1	237.0	168.0
Mean	4.59	6.69	9.01	2.95	1.84	1.59	120.52	96.39
SD	1.22	2.23	2.16	0.75	0.36	0.36	63.47	34.04

Note. cm = centimeters; s = seconds; m/s = meters/second; N = Newton

Table 4

20M Sprint Capacity Test Outcome Variables Correlation Matrix

	Class	Yrs Prev.	Yrs Post	Hrs/ week	Age	Coach Ratings	VAS scale rating g [cm]	Stop watch	Speed [m/s]	Push Length°	Push Freq.	Peak/ Force Ratio [N]	Peak Force [N]
Yrs Prev.	-.109												
Yrs Post	.707**	.292											
Hrs/ week	-.008	.066	.171										
Age	.260	.473	.527*	.263									
Coach's Rating	.135	.213	.316	.443	.275								
VAS scale rating [cm]	.376	.220	.488*	.543*	.378	.932**							
Stop- watch	-.832**	.016	-.542*	-.235	-.084	-.169	-.459						
Speed [m/s]	.87**	.021	.547*	.060	.091	.159	.408	-.956**					
Push Length°	.670**	.117	.497*	.145	.149	.225	.358	-.626**	.650**				
Push Freq.	.377	.271	.256	.011	.260	-.017	.098	-.450	.594*	.160			
Peak/ Force Ratio [N]	.259	.041	.112	.229	.112	-.103	.010	-.321	.350	.654**	.325		
Peak Force [N]	.372	.037	.187	-.072	.052	-.238	-.095	-.459	.540*	.509*	.516*	.845	

Note. *Correlation is significant at the .05 level, **correlation is significant at the .01 level
 cm= centimeters; s= seconds; m/s= meters/second; N=Newton; Yrs Prior= Years of athletic experience prior to the onset of disability; Yrs Post= Years of athletic experience after the onset of disability; Yrs Prior and Yrs Post=11 (>10 years of experience); 2-tailed correlations were determined at the ($p<.05$) significance level.

1) Is there a relationship among push technique as measured by push length in degrees, push frequency, peak/average force ratio, and peak force and speed performance as measured in meters/second by the *SmartWheel®*?

Table 5 presents information pertaining to measured speed performance in meters/second on the *20M Sprint Capacity test* and other potential speed related variables collected by the *SmartWheel®*. Results indicated significant relationships among the speed-related components of push length ($r = .650, p = .005$), push frequency ($r = .594, p = .012$), peak force ($r = .540, p = .025$) and speed (m/s) as measured by the *SmartWheel®*. The relationship between peak/average force ratio and measured speed (m/s) was not statistically significant ($p = .168, r = .350$).

As previously stated, due to the high correlation between speed (m/s) and classification level, partial correlations were calculated to control for the influence of level of disability on performance. Several variables that had significant bivariate correlations were not correlated when the effect of classification level was partialled out. When athlete classification (i.e., class) was partialled out, push length and speed were no longer significantly correlated ($r = .175, p = .532$). Push frequency and speed (m/s) remained significantly correlated ($r = .573, p = .026$); however, peak force and speed (m/s) also were no longer significantly correlated ($r = .464, p = .081$). These results indicated a moderate effect of the variables of push length ($r = .65$), push frequency ($r = .59$), and peak/average force ratio ($r = .54$) on an athlete's speed measured by the *SmartWheel®* in meters/second.

Table 5

Correlations between SmartWheel® measured speed and other speed performance variables

		Speed [m/s]	Push Length in °	Push Frequency	Peak/average force Ratio	Peak Force [N]
Push Length in°	Correlation	.650				
	Sig.	.005				
	Partial Corr.	.175				
	Sig.	.532				
Push Freq.	Correlation	.594	.160			
	Sig.	.012	.539			
	Partial Corr.	.573	-.193			
	Sig.	.026	.490			
Peak/Avg. Force Ratio [N]	Correlation	.350	.654	.325		
	Sig.	.168	.004	.203		
	Partial Corr.	.241	.657	.188		
	Sig.	.386	.008	.502		
Peak Force[N]	Correlation	.540	.509	.516	.845	
	Sig.	.025	.037	.034	.000	
	Partial Corr.	.464	.345	.390	.818	
	Sig.	.081	.207	.151	.000	

Note. m/s= meters/second; Push Length in° = Average length of the push in degrees; Push Frequency [1/s] = How many times per second, on average, the subject pushes on the SmartWheel®; N= Newton.

2) What are the relationships among the *20M Sprint Capacity Test* and commonly used methods (coaches' rating, classification, and stopwatch assessment) for assessing speed in disabled sports performance?

Appendix G presents four scatter plots, which show the relationships between performance on the *20M Sprint Capacity Test* and the coaches' ratings. The relationship between

performance on the *20M Sprint Capacity Test* and the other commonly used methods for assessing speed in wheelchair sports, of classification, and stopwatch assessment, are presented in Table 6. The sample size for analyzing this research question was 16 as one of the participants was new to the sport of quad rugby and at the time of testing had not been formally classified. Significant relationships were found between functional classification and speed ($p < .001$) measured by the *SmartWheel®*. Simple effect size interpretation ($r = .859$) indicated a strong relationship between functional classification of the athlete and measured speed. Given this association, partial correlations were further examined to control for the influence of classification when analyzing these commonly used methods for assessing speed and performance on the *20M Sprint Capacity Test*. Stopwatch measured speed and the speed measured by the *SmartWheel®* were highly correlated ($r = -.956, p < .001$), which was anticipated when classification was controlled. A significant relationship ($r = -.810, p < .001$) was also found between functional classification of the player and stopwatch measured speed. Coaches rating of the players' they coach were based on the coach's interaction with his particular team and not the cumulative sample size of all four teams. Due to the coaches' relative ability to rate only their particular teams, within the particular sport of either wheelchair basketball or rugby, scatter plots were examined to look for relationships between the sport of either wheelchair basketball or wheelchair rugby and the two types of ratings that coaches were asked to used to rate the player's of their particular team. Although the sample size of participants was small, a visual examination of the four scatter plots for each sport and type of coach rating provided indication that there were some positive relationships between some of the coaches' ratings and measured speed. Figure G1 indicated a weak to moderate linear association between the wheelchair basketball coaches' VSA ratings and athlete speed. Figure G2 indicated

a moderate positive linear association between the ratings of basketball coaches and athlete speed. Figure G3 indicated a weak to moderate linear association between the VAS ratings of wheelchair rugby coaches and athlete speed. Finally, Figure G4 indicated a near zero to weak linear association existed in Likert ratings of wheelchair rugby coaches and athlete speed.

Table 6

Correlations between Smartwheel® measured speed and alternative measurement methods

		Speed [m/s]	Class	Stopwatch speed [s]
Class	Correlation	.859		
	Sig.	.000		
Stopwatch [s]	Correlation	-.956	-.810	
	Sig.	.000	.000	
	Partial Corr.	-.865		
	Sig.	.000		

Note. Class=Player functional classification level, Stopwatch=speed in seconds on stopwatch, VAS=Visual Analog Scale in cm, [s] = seconds.

3) What are the relationships among demographic variables (influence of classification level, previous years of athletic experience prior to disability, years of experience playing the sport post-onset of disability, hours of practice per week, and age of athlete) and the speed on the 20M Sprint Capacity Test?

Table 7 displays the relationships between demographic variables and performance on the 20M Sprint Capacity Test. Years of experience playing the sport after the onset of the disability and speed were significantly correlated ($r = .547, p = .023$). The relationship between years of previous athletic experience prior to onset of the disability and speed, however, were not significantly correlated ($r = .021, p = .935$). Given the influence of classification on speed and other performance variables, partial correlations were again examined to remove the potential

effect of classification on the correlations between demographics and performance test results.

Following partial correlations, measured speed and years of experience after the onset of the

disability also yielded a non-significant relationship ($r = -.224$, $p = .421$). The relationship

between speed as measured by the *SmartWheel*® and years of experience playing the sport after

the onset of disability was moderate ($r = .547$).

Table 7

Correlations between SmartWheel® measured speed and performance variables

		Experience Pre- Disability	Experience Post- Disability	Practice Hours Per Week	Player Age	Speed [m/s]
Experience Post- Disability	Correlation	.292				
	Sig.	.256				
	Partial Corr.	.346				
	Sig.	.207				
Practice Hours/Week	Correlation	.066	.171			
	Sig.	.801	.512			
	Partial Corr.	-.005	.194			
	Sig.	.985	.487			
Player Age	Correlation	.473	.527	.263		
	Sig.	.055	.030	.307		
	Partial Corr.	.487	.419	.255		
	Sig.	.066	.120	.360		
Speed[m/s]	Correlation	.021	.547	.060	.091	
	Sig.	.935	.023	.818	.729	
	Partial Corr.	.115	-.224	.122	-.388	
	Sig.	.683	.421	.666	.153	

Note. Experience Pre-Disability, Experience Post-Disability= time in years; Age=years; m/s= meters/second.

Discussion

A set of field-tests that measures athletes' progress and level of achievement in an indoor environment is critical in examining athletic performance (Vanlandewijck, Daly, & Theisen, 1999). This pilot study attempted to use the *SmartWheel®* as the measurement tool to assess potential relationships between performance on a newly developed field test, the *20M Sprint*

Capacity Test, and other commonly utilized methods of evaluating speed. By focusing on speed performance, this study attempted to begin the process of elucidating optimal speed-related push techniques and aimed to enhance the understanding of factors related to speed assessment techniques. In completing this study and reviewing other relevant literature, the researcher indicates that a continued necessity exists for developing strategies for assessing speed among wheelchair sports athletes; expanding investigation of similar wheelchair sports speed assessment studies on a larger scale; and continuing research to further the development of wheelchair sports push technique training and assessment protocols related to athlete speed performance.

Limitations. Several limiting factors were encountered during this study that affected this study's findings. The limitations were similar to those experienced in other disabled sport research. Participation in wheelchair propulsion studies has been limited to a small number of experienced wheelchair users (Vandlandewijck et al., 1994). Limited numbers of disabled sport participants continue to make randomization in large-scale studies difficult as well (Barfield & Malone, 2012).

Logistical sample size difficulty. A major challenge faced in this pilot study was the difficulty in collecting an adequate sample size to complete in-depth analyses. This limiting factor prohibited larger conclusions to be made regarding the validity and reliability of the *20M Sprint Capacity Test*. The limited number of disabled sport participants is not uncommon to this type of research and has been experienced by other wheelchair sports performance studies (Stankovits, 2000; Van der Woude, 2001).

Limited accessibility to wheelchair sports teams in the southeastern region of the United States created a sample size limitation as it prevented convenient proximity to accessing a larger

sample size. Barfield and Malone (2012) stated that regional bias existed in their study regarding performance testing of quad rugby players, as well. In addition, accessibility to athletes who may have been interested in study participation was hindered by difficulty in gaining support from regional team contacts that served as gatekeepers to athlete participation.

While the teams who participated were well organized, some coaches indicated that it is inherently difficult in these sports to have consistently well-attended practices. As previously discussed, of the approximate 100 potential participants, only 17 participants completed the study. These 17 were members of four teams, which had a total potential population of 36 participants. A 47% attendance rate during data collection dates and times contributed to a smaller sample size. Small sample size of seventeen participants should be noted when interpreting this study's correlation coefficients. Thus, it is important that the correlations found in the present study be interpreted with caution. In the future, small sample size limitations could possibly be prevented through the contribution of additional research dollars. This additional funding may provide researchers with the resources needed to travel to farther destinations to work with more teams and to provide players, coaches, and tournament organizers with incentives to participate.

Equipment related sample size difficulty. As previously mentioned, the only *SmartWheel*® size currently available to the researcher required a 24-inch wheel rim size. All of the athletes who participated in this study, with the exception of one individual, used a sports wheelchair which required a wheel size other than the provided 24-inch size. This restricted players from completing the testing in the chair they typically use. This may have been limiting to their experience and performance if the provided chair was awkward or uncomfortable for them. Sabick et al. (2004) discussed the importance of participants using their own specific

wheelchair as it helps participants avoid changing their propulsion style based on the alternate wheelchair used for performance testing.

The unique handrim of the *SmartWheel*® may have also been a contributing limitation as this handrim was not equal to the size and thickness of the wheel on the other side of the chair. Based on athlete comments, this may have been uncomfortable for the athlete to use. Many of the athletes have varying levels of grip strength and motor skills depending in part on their various disabilities (Stankovits, 2000). These varying levels may make the handrim difficult to use or become accustomed to for some athletes with lower levels of grip strength and motor skills. Past studies have shown that propulsion with a larger handrim resulted in improved mechanical efficiency (Goosey-Tolfrey & Moss, 2005). This larger handrim may allow for some athletes with less grip strength to grip the handrim with a larger diameter easier than without a larger handrim. For some athletes, the unique handrim required by the *SmartWheel*® may have assisted with performance for some athletes while making it difficult for others to use properly and effectively. In the future, additional research funding would allow for the purchase of more equipment items, allowing for multiple *SmartWheel*® devices and handrims in different sizes be purchased. This may help to better accommodate a larger population of potential participants.

Extraneous performance factors. Additional limitations may have occurred due to extraneous factors that may have impacted the athlete's performance uncontrolled by the researcher. These possible limitations included: physical activity level of the athlete outside the sport setting, onset of any secondary health conditions during and directly prior to the period of measurement, and other unknown psychosocial factors which may have affected performance on the *20M Sprint Capacity Test*. In addition, the lack of normative data of similar field-based speed performance studies to compare with *20M Sprint Capacity Test* results also was a limitation.

Interpretation of results. While this study had numerous limitations that may have influenced or limited the generalization of findings, there were results worthy of further discussion and interpretation. These results included Development of a Speed-Related Push Technique, Improving Speed Assessment, and Understanding Factors Related to Speed Assessment.

Development of the speed-related push technique. Although the results of this study did not show correlations between push length, push frequency, peak force, and speed performance when accounting for athlete classification levels, the process of developing an optimal push technique is still an area of research to be investigated. When controlling for disability classification, there was a relationship between push frequency and speed ($r = .573$, $p = .026$). While this finding is presumed to have existed, the confirmation of this relationship is limited in previous literature related to wheelchair sports performance.

The need for more understanding and standardization of the many sport specific performance factors has been documented in prior research (Cooper, 1990; Sarro et al., 2010; Van der Woude, 2001). The information provided through future continued research of understanding those speed-related push techniques may help formulate a more standardized training protocol for coaches to implement with their athletes. Several researchers have studied particular push techniques, but a standardized and objective best method for wheelchair sports propulsion is still unclear and should be further investigated. Chow et al. (2001) concluded that greater push time and push angle using a para-backhand push technique provided users the opportunity to transmit more force to the wheel, giving these users a faster overall movement speed. While the study under examination discusses techniques for improved speed, other performance studies have indicated that push economy should be the focus, stressing the need for

a lowered push frequency (Goosey, Campbell, & Fowler, 2002). At this time, it is unclear as to the specific propulsion technique that results in the best athletic performance. Expanded biomechanical and physiological research in this area may help to contribute to the formation of optimal wheelchair push performance techniques.

Improving speed assessment. Speed data collected from the *SmartWheel®* were examined in relationship to other commonly used methods of assessing speed (a stopwatch measurement, Likert-type coach rating scale, and a VAS scale) as well as against demographic variables that could potentially affect an athlete's speed performance. The subjective rating assessment of player's speed by coaches was important to this study because coaches have the best opportunity to assess the speed of their athletes as they interact with them regularly through practice, games and competitive tournaments. The results of this study were based on coaches rating of his particular team and not the cumulative sample size of all four teams. An examination of scatter plot results indicated that a moderate positive relationship may exist between coaches' ratings and measured speed. Scatter plot results of coach ratings using the VAS scale indicated that results may be more closely associated with speed using the VAS scale than when using the Likert-type scale to rate speed. This may indicate the VAS scale was a more appropriate tool for coaches to measure subjective rating of speed than the Likert-type scale. The Likert-type scale of coach ratings indicated that coach ratings of speed on the basketball teams seem to be more highly associated with measured speed in m/s than the rugby coach ratings as the rugby coach ratings using the Likert-type scale did not indicate an association with measured speed. The reasons for these associations with measured speed were not further investigated as they reached beyond the scope of this study. The VAS analysis indicated that the basketball coaches' ratings of speed and the rugby coaches' ratings of speed appeared to result in a similar

relationship.

While three of the four scatter plots indicated a weak to moderately positive relationship between the two types of ratings and measured speed in m/s, further research should continue to examine the implementation of objective speed assessments in order to conclude whether or not this form of speed assessment is useful for coaches and athletes to accurately assess performance speed. In summary, coaches' rating of speed may have also been related to assessing speed during game situations while the *20M Sprint Capacity Test* simulates a speed that is was isolated during the test and different in the context of the sport.

After completing the study, the researcher recommends that with further research, athlete speed assessment training for coaches should be further established and researched in order to assist coaches in developing optimal speed related skills push propulsion techniques. While previous studies did not focus solely on speed assessment, previous studies (Robbins, Houston, & Dummer, 2010; Tawse et al., 2012) found that disability focused coaching techniques and philosophies were in need of further development. Robbins, Houston, and Dummer found no specific coaching characteristic, which ensured success, but rather pointed to the relationship between the coach and athlete and the coaches' willingness to develop athletes as people as the markers of success. Similar to Olympic competition, coaches and scientists are continually looking for speed assessment methods for Paralympic sport (Barfield & Malone, 2012). A review of literature as well as the results of this particular study continues to suggest a further development of objective speed assessment techniques.

Understanding factors related to speed assessment. Athlete functional classification level and speed performance on the *20M Sprint Capacity Test* were highly correlated in this study ($r = .859$). In a similar performance based study of wheelchair rugby players, when

traveling at a velocity of 2.7 m/s, the distance covered was strongly correlated to the player's functional classification level ($r = .62$), suggesting that player classification can be related to functional ability regarding wheelchair propulsion (Sarro et al., 2010). These findings were to be expected as athletes with higher classification levels have more trunk control and less upper-extremity neurological impairment (IWBF, 2010; IWRP, 2011).

The physical factors involved with various disabilities and associated player classifications play an important role in developing anaerobic power, often related to speed (Goosey-Tolfrey & Moss, 2005). Currently, athletes of both wheelchair basketball and quad rugby are classified according to sport specific classification levels and requirements (IWBF, 2010; IWRP, 2011). A continued debate exists among researchers regarding the systems used for classifying athletes with disabilities (Doyle et al., 2004). Separation of the current IWBF and IWRP systems has been established to help maximize the range of players with various disabilities so that equal representation among team players exists to help foster the positions and roles unique to the sport (Tawse et al., 2012). Others have proposed changing the sport specific classifications since the current systems do not draw on skill proficiency of the individual athlete (Vanlandewijck, Spaepen & Lysens, 1995). Instead, adding quantitative evaluation methods to the current traditional classification methods may lead to a more evidence-based system (Sarro et al., 2010). The modified classification scale created and utilized for this study, should continue to be investigated. This less specific classification system may provide a more objective method of classifying athletes across multiple sports.

Demographic factors that were collected to examine any potential relationship factors with speed only indicated correlations between years of experience playing the particular sport they played and measured speed. No significant relationship was found between years of athletic

experience prior to the onset of disability and measured speed. In terms of the future development of wheelchair sports, however, the lack of correlation between years of athletic experience prior to the onset of disability and speed may serve as an important indication that everyone has the potential of becoming an athlete after the onset of a disability without having prior experience. This assumption should be further investigated to confirm this assertion.

Conclusion

The research findings of this study have several practical implications, which may be beneficial as a starting point for future research studies. After partialing out the effect of disability, relationships between the propulsion elements of push length and peak force were not correlated with speed performance. Push frequency and speed, however were shown to be moderately correlated ($r = .57$). Additionally, the demographic qualities of years of sport-specific experience and age were suggested as potential influences on speed performance. Future research involving investigation of the effects of these and other demographic factors should be continued to make further conclusions of their influence on speed. The growth of a respectably strong database of knowledge could emerge from such studies, leading to a more evidence-based approach to improving performance factors and the understanding of wheelchair sports (Van der Woude, 2001). Expansion of similar studies encompassing larger samples could further confirm some of the findings in this research and may contribute to the needed growth of disabled sports research.

Although this study utilized a small sample size, the results from this research may help to point future research to particular areas of studying disabled sport and wheelchair sports performance. Despite small sample sizes in the area of wheelchair biomechanics research, several studies have yielded contributions to this field with small sample sizes of fewer than 30

participants (e.g. Crespo-Ruiz, Ama-Espinosa, & Gil-Agudo, 2011; Sarro et al., 2010; Sabick, Kotajarvi, & An, 2004; Van der Woude et al., 1988). Goosey-Tolfrey and Moss (2005) concluded, in a study of wheelchair tennis players, that although the sample size was small ($N = 8$), relationships between the independent variable of trunk stability and wheelchair velocity characteristics were observed. Wheelchair sports performance continues to be an area that requires attention for researchers and practitioners. This study provides a foundation to build further practical protocols related to speed assessment among athletes with disabilities.

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Section II: Extended Literature Review

Wheelchair Basketball and Wheelchair Rugby

The use of sports in rehabilitation, both acute and long-term, has steadily increased over time. Initially, sports activities were considered a therapeutic tool and were introduced in rehabilitation treatment programs (Gil-Agudo, Del Ama-Espinosa, & Crespo-Ruiz, 2010). However, objectives and motives for disabled sports have expanded and attracted increasing numbers of spectators, establishing the professional prestige of athletes with disabilities, and earning the recognition they deserve in the mass media (Gil-Agudo et al., 2010).

Historically, elite wheelchair sports competition has grown tremendously. Four hundred athletes participated in the first Paralympic Games held in Rome in 1960 (Gil-Agudo et al., 2010). In the most recent Paralympic Games held in Beijing in 2008, 4,000 athletes from 150 countries competed (Gil-Agudo et al., 2010). This increase in sport participation has occurred in part, due to the many physical and psychological benefits that engaging in sports has for people with disabilities (Hanson, Nabavi, & Yuen, 2000). The importance and interplay of sports and manual wheelchair users will be outlined in the following section.

Research since the early 1980s documents that engagement in sports leads to improvement in strength, coordination, balance, endurance, pulmonary function, and weight control for people with spinal cord injuries (Hanson et al., 2000). Because of these benefits, as well as other well-documented physiological and psychological benefits of sports, the use of sports in rehabilitation has gradually gained popularity (Hanson et al., 2000). This increased popularity is important to this specific study as many wheelchair sport athletes were first exposed to sports, such as wheelchair basketball and wheelchair rugby, in their rehabilitation experiences.

Wheelchair basketball is the most popular team sport in Paralympics competitions (Wang, Chen, Limroongreungrat, & Change, 2005). According to estimates of the International Wheelchair Basketball Federation (IWBF), the number of players worldwide is 30,000 (Gil-Agudo et al., 2010). The components, rules, and requirements to play wheelchair basketball, help to make the sport accessible to athletes and helps support the popularity of the game.

The sport of wheelchair basketball is characterized by intermittent high-intensity activity for wheelchair maneuvering and ball handling (Wang et al., 2005). These wheelchair maneuvers often consist of propulsion, starting, stopping, sprinting, braking, and direction changes of the wheelchair (Wang et al., 2005). It has been recommended that in order to help wheelchair basketball players perform successfully in competition, important factors related to a successful performance should be identified (Wang et al., 2005). Numerous research papers have focused on the sport of wheelchair racing; however, limited studies have been conducted in wheelchair basketball (Wang et al., 2005). The development of the *WSPT* will help to address these important factors of maneuverability that relate to wheelchair basketball.

Wheelchair rugby, originally called murder ball or quad rugby, was created and implemented specifically for athletes with cervical spinal cord injuries (Vanlanderwijck et al., 2001). The sport originated in Canada and was first played only by tetraplegics in the 1970s (Morgulec-Adamowicz, Kosmol, Bogdan, Molik, Rutkowska, & Bednarczuk, 2010). The game was first played in the United States in 1981 and was further developed by the United States Quad Rugby Association in 1988 (Gulick et al., 2006). With the increased popularity of the sport, a need arose to include athletes with other disabilities with impairments similar to tetraplegia (Morgulec-Adamowicz et al., 2010). These impairments include muscular dystrophy,

cerebral palsy, and other neurological disorders (Morgulec-Adamowicz et al., 2010). Presently, wheelchair rugby athletes are individuals with neurological disorders or non-neurological disorders with impaired or absent upper and lower limb movement (Morgulec-Adamowicz et al., 2010). Wheelchair rugby was introduced into the Paralympics in 1996, during the Atlanta Games (Abel, Peters, & Platen, 2003). This worldwide exposure to the sport helped establish the game as a competitive and performance oriented sport in addition to its well-known rehabilitative and therapeutic objectives in adaptive sports (Abel et al., 2003). Twenty-nine countries actively play wheelchair rugby at different international competition levels (Morgulec-Adamowicz et al., 2010).

Wheelchair rugby is a full contact sport in which teams score by passing or carrying a rugby ball (volleyball) across the end line of a basketball court (IWRF, 2011). Due to the varying physical capabilities of each player's hands, a variety of techniques are used to pass the ball (Gulick et al., 2006). Defensively, players involve their wheelchair to perform technical and tactical elements of the game such as picking and blocking (Morgulec-Adamowicz et al., 2010). Due to the full contact nature of the sport, players also use their wheelchair to collide into opponents, in an effort to jar the ball free (Gulick et al., 2006). The main set of skills necessary to play wheelchair rugby includes: speed, strength, endurance, coordination, and efficient wheelchair maneuverability skills (Morgulec-Adamowicz et al., 2010).

The major difference between wheelchair basketball and wheelchair rugby players is their physical profile (Vanlanderwijck et al., 2001). Wheelchair rugby requires players who have disabilities affecting all four limbs (Sarro et al., 2010). The required level of injury to participate in wheelchair rugby is restricted to individuals with upper extremity and lower extremity functional impairments and depends on the level and completeness of the impairment

(Vanlanderwijck et al., 2001). Wheelchair rugby players often firmly strap themselves to the frame of their wheelchair to increase their balance and to prevent falling or shifting of the sitting position during points of impact with other players (Vanlanderwijck et al., 2001). Conversely, wheelchair basketball is played with a group of athletes, mostly with full or at least greater functional potential of the upper extremities (Vanlanderwijck et al., 2001). These differences in range of action, determined by trunk control, are compensated for by the sport-specific functional classifications (Vanlanderwijck et al., 2001). These sport specific classifications will be further discussed.

Wheelchair Sports Classification

A fervently debated aspect of disabled sports is the various sport classification systems (Gil-Agudo et al., 2010). The classification process is best described as a method of functional evaluation of an athlete with a disability for the purpose of placing him or her in the most appropriate level of competition (Doyle et al., 2004). As used in athletics, functional classifications focus on an athlete's ability to perform sport specific skills (Doyle et al., 2004). Classifications were originally established in an attempt to guarantee fairness of results and ensure equal opportunities for athletes with different types and grades of disability (Vanlandewijck et al., 1995). A basic goal of classifications was to ensure that winning or losing an event depended on talent, training, skill, fitness, and motivation as opposed to unevenness of disability-related variables among competitors (Gil-Agudo et al., 2010). Differences between performance results of various sports achieved by athletes within given classes are usually smaller than they would be between non-classified athletes (Morgulec-Adamowicz et al., 2010).

Originally, no classification system existed within wheelchair sports (Gil-Agudo et al., 2010). However, as such sports became more popular, it became apparent that open competitions

favoured athletes with less functional disability (Gil-Agudo et al., 2010). The first classification system established one class for paraplegics and another for tetraplegics (Gil-Agudo et al., 2010). This initial division further led to a subdivision into various classes using as a consistent reference, the level of spinal cord lesion (Gil-Agudo et al., 2010). Sport engagement for individuals with disabilities was historically promoted mostly by physicians and physical therapists (Morgulec-Adamowicz et al., 2010). As athletes with different physical impairments other than spinal cord injuries began to compete, classification systems were developed based on anatomic and medical criteria, such as assessment of muscle strength, range of motion, length of limb stump, level of spinal cord injury, or spasticity (Morgulec-Adamowicz et al., 2010). This, however, limited each specific disability group to compete separately based on these divisions (Gil-Agudo et al., 2010).

The current classification system was used for the first time in international competition in July of 1984 at the 7th Annual World Paralympic Games in Aylesbury, UK (Crespo-Ruiz, Ama-Espinosa, & Gil-Agudo, 2011). Despite the increased popularity of wheelchair basketball and attention athletes have gained from researchers, no change to the National Wheelchair Basketball Association classification system has been made since its adoption in 1984 (Doyle et al., 2004). This classification system allowed athletes with different physical impairments to compete with one another (Gil-Agudo et al., 2010). Within this system, people from various impairment groups were included in the same class and classifications became sport and event specific, rather than impairment specific (Gil-Agudo et al., 2010). International classifiers define functional classification in disabled sport as the ordering of competitors into classes according to their performance potential, based on the relation between impairment and sport activity (IWBF, 2002). In abiding by this definition, classification criteria should be based on the relation

between the functional potential of the athlete and the performance determinants of sport-specific performance (Gil-Agudo et al., 2010).

This functional classification system has been the subject of much debate and research. Some supporters of this classification system maintain the notion that this model increases the scale of competition by reducing the number of classes, helping to ensure that a significant number of athletes create credible competition within each class (Gil-Agudo et al., 2010). Some researchers have also stated that the sport specific classification system in use is understandable due to the particular sport specifications (Gil-Agudo et al., 2010).

Contrasting these views, others have proposed that the system may be difficult for classifiers to accurately place athletes in appropriate categories because of the large number of impairments that are considered simultaneously (Gil-Agudo et al., 2010). While classification types and methods are still often debated, wheelchair sports in general continue to progress in popularity and continue to advance technologically with regards to the equipment required to play these sports. Advancements in sport wheelchairs have helped athletes compensate for many of the physical deficits currently accounted for in classification systems (Doyle et al., 2004). Specialized sport chairs often bridge the gap between players of different disabilities as players grow in their experience and learn how to customize their wheelchairs to enhance their abilities (Doyle et al., 2004). For example, athletes with low levels of trunk control can angle the back of seat downward so that they are in a posture with their trunk resting against their upper thighs for support providing more stability and balance for increased wheeling efficiency (Borisoff & McPhail, 2011).

Due to advances in sport wheelchair technology, the classification systems first created when athletes competed in a traditional wheelchair may no longer prove appropriate for today's

athletes and levels of competition (Doyle et al., 2004). Additionally, functional classification may penalize the best athletes and improperly classify new athletes who have not yet reached their functional potential (Gil-Agudo et al., 2010). Few researchers have raised objections to using data based on objective methods to attempt to characterize and validate each of the groups defined in the functional classification system (Gil-Agudo et al., 2010). The literature on this topic of objective measurement is sparse and rarely scrutinized (Gil-Agudo et al., 2010).

Within the sport of wheelchair basketball, functional classification is based on the player's capacity to perform the playing skills of: pushing, pivoting, shooting, rebounding, dribbling, passing, and catching (Gil-Agudo et al., 2010). It is important to note that classification according to these functional skills is not based on the skill level of the players, but rather on the player's functional capacity to complete each task (Gil-Agudo et al., 2010). This classification for basketball divides players into four classes (IWBF, 2002). Each player is assigned a sport classification from 1 to 4 with intermediate 0.5 classes for exceptional cases that do not fit exactly into one class (IWBF, 2002). Class I players are categorized as having no functional sitting balance when in a wheelchair without back support to Class IV players who are categorized as having optimal sitting balance and optimal trunk movements in all planes (IWBF, 2002). Wheelchair basketball classifications become important to teams because the total number of player points for any given team configuration, meaning the sum of the points of all 5 players on the court, is 14.0 (IWBF, 2002).

Earlier studies attempted to validate the currently used wheelchair basketball classification system using field performance of elite athletes (Crespo-Ruiz et al., 2011). These studies, however, have not used an advanced objective measurement tool such as the *SmartWheel®* to measure specific speed related performance elements such as those elements

included in the current study. Crespo-Ruiz et al. suggested that it would be of interest to further explore the biomechanical analysis of player classes to support or refute the classification system with more objective data on how particular skills are performed (Crespo-Ruiz et al., 2011). Currently, categorizing players into various classifications is based on the subjective observations of the classifiers and not on objective performance measurements (Crespo-Ruiz et al., 2011).

The functional classification system for wheelchair rugby players allows for comparisons of potential functional abilities of athletes within the accepted classification criteria (Morgulec-Adamowicz et al., 2010). The classification system currently used by the United States Quad Rugby Association (USQRA) was adopted from the International Wheelchair Rugby Federation (IWRF) in 2005 (USQRA, 2012). The current classification system for wheelchair rugby includes uses three off the court components to determine players' classification levels (IWRF, 2011). These three off the court tests are the bench test, functional trunk test, and functional movement test (USQRA, 2012). In addition to these three tests, athletes are observed while playing to help classifiers determine in which classification group to place an athlete (USQRA, 2012). Following these assessments, athletes are placed into one of seven 0.5 incremental sport classes (numerical categories) ranging from 0.5 to 3.5 points (IWRF, 2011). In general, the 0.5 class includes athletes with the least function and the 3.5 class includes athletes with the most function eligible to play wheelchair rugby (Morgulec-Adamowicz et al., 2010). Similar to basketball, there is a limit to the number of points a team may have on the court at any given time. In wheelchair rugby, the total number of points for all four athletes on a team on the court at any particular time may not exceed 8.0 points (IWRF, 2011). Although the growing emphasis on functional assessment in this classification process has led a number of researchers to

examine the relationships between wheelchair rugby specific fitness tests and player classification, few studies have focused on speed assessment and factors related to speed (Morgulec-Adamowicz et al., 2010).

While classifications are based on the movement potential associated with neuromuscular function and performance or actions related to wheelchair rugby, it is not well known how functional classification correlates with variables related to performance, such as distance covered (Sarro et al., 2010). Intending to further examine this relationship between classification and performance, Sarro et al. investigated correlations as measured by distance covered during a game. Researchers found moderate to strong correlations ($r=0.6$, $p=.01$) between classification levels of wheelchair rugby players and distance covered during a game (Sarro et al., 2010).

While classification is an important aspect within disabled sports, classification can be limiting in the potential performance of athletes that may surpass the expected level of function within their classification level (Morgulec-Adamowicz et al., 2010). The lack of equivalent assessment tools across both disabled and non-disabled sports has further contributed to the limited reliance on any commonly applied game efficiency assessment tools (Morgulec-Adamowicz et al., 2010). Morgulec-Adamowicz et al. confirmed that a lack of appropriate assessment tools in sports for individuals with disabilities exists (Morgulec-Adamowicz et al., 2010). The continued need for the development of objective speed assessment measures in both wheelchair basketball and wheelchair rugby studies, may be addressed by utilizing the *SmartWheel®* to develop such speed assessment tools.

Speed Assessment Techniques

Techniques to improve speed performance, improve training, and selecting players are primary concerns of coaches and researchers involved in wheelchair basketball (Wang et al., 2005). This particular study focused only on speed performance skills. For most sports, a modification to physical training has more potential to enhance performance than any other modification (Liow & Hopkins, 1996). An aspect of training that has been neglected by sport scientists working with athletes with disabilities is the specificity of training (Liow & Hopkins, 1996). The *20M Sprint Capacity Test* examined in this study addresses the specific skill of speed assessment.

Currently, coaching evaluations to improve technique and training are based on subjective opinions of the coaches. Few studies, such as the Wang et al. (2005) study, have attempted to use some form of rating system to evaluate wheelchair basketball athletes. The coaches' ratings of players was used in this study as part of a research purpose to explore the relationship between wheelchair basketball performance and fundamental factors involved with wheelchair basketball (Wang et al., 2005). While this research is beyond the scope of the skills evaluated by the *20M Sprint Capacity Test*, the Wang et al. (2005) study similarly attempted to apply an objective measure to a performance evaluation. Within this study, researchers asked team coaches to rate overall performance on a scale from 1 to 10 points with "10" being the most effective and "1" being the least effective (Wang et al., 2005). The performance of athletes was evaluated based on the participant's effectiveness in the offense and defense of the wheelchair basketball games during their team's competitions including the season statistics (Wang et al., 2005). The elements of performance for each participant evaluated was determined based on the average number of points, rebounds, assists, blocks, and steals per game in the season

competitions (Wang et al., 2005). Similarly, coach rankings will be used in this study to examine correlations between the *WSPT* and the coach's rating of players based on perceptions of the speed of the athlete.

SmartWheel® Wheelchair Propulsion Elements

Disabled sports performance optimization has increasingly focused on the importance of biomechanics (Gil-Agudo et al., 2010). Optimizing athletic performance has been approached from the perspectives of ergonomics and skill proficiency (Gil-Agudo et al., 2010). Biomechanical analysis techniques have been suggested to be most appropriate for contributing scientific evidence to the validation of different methods of classification (Gil-Agudo et al., 2010). By utilizing the *SmartWheel®* within studies such as these, measurements of three-dimensional hand rim forces for dynamic movements can be collected (Gil-Agudo et al., 2010). The *SmartWheel®* can also be used to study force-generation strategies under sport-specific conditions, making it possible to address all the movement components of a particular sport such as starting, wheeling, braking, and turning (Gil-Agudo et al., 2010). Further, almost all currently available literature uses subjective, qualitative techniques based on coaches' opinions to analyze player's performance abilities (Gil-Agudo et al., 2010). Thus, it is imperative that objective assessment measures continue to be developed in order to contribute to the current, mostly subjective speed evaluation process.

In order to discuss the complexities of manual wheelchair propulsion and its effects on manual wheelchair users, it is necessary to understand the elements of wheelchair propulsion. The propulsion cycle often referenced is commonly divided into two phases; the push (drive, stroke) phase and the recovery phase (Vanlandewijck et al., 2001). The push phase is defined as the force production phase when the hands are in contact with the rims. The recovery phase

occurs during the non-propulsion phase when the hands are being positioned to restart the push phase (Vanlandewijck et al., 2001). Electronic instruments have previously been developed to register contact between hand (glove) and hand rim (Vanlandewijck et al., 2001). This contact, however, does not mean that force actually is applied (Vanlandewijck et al., 2001). It has therefore been suggested that identification of hand contact/hand release by means of direct registration of the forces applied on the hand rims be measured (Vanlandewijck et. al., 2001). The ability to collect this data in real time is a unique feature of the *SmartWheel®* and allows for data collection in actual sport specific settings.

The ability of the *SmartWheel®* to collect data in applied settings is supported by current literature, which confirms the need for applied *SmartWheel®* testing in settings other than those of acute rehabilitation hospitals. Further, it is also indicated that the level of wheelchair propulsion testing, which the *SmartWheel®* is capable of providing, has not extensively been explored in current research studies. Therefore, a need exists to provide both *SmartWheel®* research in an applied and clinical settings among populations of both athletic and non-athletic manual wheelchair users. This study addresses the population of athletic manual wheelchair users in an applied research setting.

Section III: Extended Discussion

The results from this study were focused on evaluating the potential relationships between selected athletes' performances on the *20M Sprint Capacity Test* utilizing *SmartWheel®* technology and other commonly utilized evaluations of performance speed. By focusing on speed performance, this research attempted to investigate speed-related push techniques for athletic performance among wheelchair athletes and aimed to enhance the understanding of particular factors related to speed assessment techniques. Demographic factors were examined to investigate any potential demographic variable effects on performance speed. Results of this study were limited by several factors. Although restricted by sample size, outcomes of this study indicated the continued necessity of future research that focuses on developing potential speed-related push technique protocols; expanding speed performance wheelchair studies on a larger scale; and continued research to develop training protocols for speed related skills for wheelchair sports athletes. Future research to continue developing objective speed assessment techniques, protocols, and strategies; as well as, continued research in studying disabled sport and wheelchair sports are indicated as a result of this research. Further investigation of these results was potentially limited by several factors.

Limitations

Logistical sample size difficulty. One of the major challenges faced in this pilot study was the difficulty in collecting a large enough sample size which would allow for a more in depth and accurate conclusion to be made regarding the validity and reliability of this performance test. The limited number of disabled sport participants makes randomization in larger scale studies difficult as well (Barfield & Malone, 2012). As previously stated, of the

approximately 100 potential participants, only 17 participants completed the study.

There are several reasons why this small sample size occurred.

The limited accessibility to disabled sports teams in the southeastern region of the United States created a limitation as it prohibited convenient proximity to access a large sample size. This is not a limitation solely experienced by this study. In a study regarding performance testing of elite wheelchair rugby players, the primary stated limitation was also regional bias (Barfield & Malone, 2012).

Additionally, a major hindrance to obtaining a large sample size was the difficulty in gaining the support from regionally located teams. Accessibility of reaching athletes and trouble with coordination of this study with regional contacts created a significant barrier to recruiting a larger sample size.

Additionally, while the teams who participated are well organized, it is inherently difficult in these sports to have consistently well-attended practices. In this study alone, the four teams, which participated, had a total potential of 36 participants. This potential population yielded 17 participants, resulting in a 47% attendance rate to team practice. This was also an unforeseen limitation to this study.

Given these limitations to obtaining a larger sample size, this small number could possibly be prevented in the future through additional research dollars which would provide for funding to allow researchers to travel to farther destinations in order to work with more teams, to purchase additional *SmartWheels®* with different rim sizes to accommodate athletes performing this test in their personal chair, and to provide incentives to these teams to participate.

The difficulty in obtaining large samples for wheelchair-related biomechanics studies has been experienced beyond the scope of this particular study. Although research has progressed,

this field of study is still hindered by methodological limitations including small numbers of a population to study as well as inconsistent methods and technologies used in these studies (Van der Woude et al., 2001). Further, Van der Woude et al. called for a need for consensus among researchers regarding methodology and strategy for biomechanics related wheelchair studies, as well as a consistent need for collaboration to improve the sample size of research studies, which could improve the power of research results (Van der Woude et al., 2001).

Equipment related sample size difficulty. Regarding limitations pertaining to the *SmartWheel®* equipment alone, several prohibiting factors contributed to this study's limitations. The *SmartWheel®* weighs 12 pounds (Three Rivers Holdings, 2008). This weight is heavier than many of the wheels outfitted for sports wheelchairs. This factor had the potential of slowing down athletes as they had not been accustomed to pushing such a heavy, bulky wheel.

As previously mentioned, the only size *SmartWheel®* currently available to researchers requires a 24-inch wheel size. All of the athletes except one participant use a sports wheelchair which required a wheel size other than the provided 24-inch size. This restricted players from using their own personal chair, which they are normally accustomed to, thus limiting their experience and comfortability in the provided chair. For many athletes, both with disabilities and without, their personal equipment and ease of using it plays a major factor in their game time performance. Forcing players to use a chair that may not properly fit them, or that they were not used to, also could have limited their performance results. In reality, the chair cannot be separated from the athlete; therefore, the chair and athlete should be considered one unit (Goosey & Campbell, 1998). From a practical standpoint, the ability of an athlete to use his or her own personal chair was not possible due to the discussed wheel size restriction.

Lastly, the *SmartWheel®* requires a unique handrim as it is manufactured to accommodate the data collection requirements. Handrim propulsion, by definition, is the guided movement that is regulated by the rim curvature and its speed and direction of movement (Goosey-Tolfrey, 2010). Although results of this study indicated that trials with the *SmartWheel®* on the left side and the right side were highly correlated ($r = .959$, $p < .001$), the handrim on the *SmartWheel®* was not equal to the size and thickness of the wheel on the other side of the chair. This may have at times made the chair provided by researchers uncomfortable for many of the athletes to use. Additionally, many of the athletes have varying levels of grip strength and motor skills in their upper limbs due in part to their various disabilities. However, past studies have also shown propulsion with a larger handrim resulted in an improved mechanical efficiency (Goosey-Tolfrey & Moss, 2005). Thus, the uniqueness of the hand rim on the *SmartWheel®* may have assisted with performance for some athletes while making it difficult for some of the players to use properly and effectively. Future research with multiple *SmartWheel®* sizes and corresponding hand rims is needed to further assess the impact of the hand rim.

Extraneous performance factors. Continued limitations may be due to any potential extraneous factors impacting the athlete's performance which are uncontrolled by the researcher. These may include: physical activity level of the athlete outside the practice and game time of the organized sport, onset of secondary health conditions during and directly prior to the period of measurement, and other unknown psychosocial factors which may affect performance on the *20M Sprint Capacity Test*. In addition, the lack of normative data to compare with *20M Sprint Capacity Test* results also contributed to study limitations.

Interpretation of Results

Justification for disabled sports research. Extending beyond the scope of examining specific performance testing techniques within the field of disabled sports, the implications of the importance of promoting a physically active lifestyle during and after rehabilitation has become an increasingly important topic within rehabilitation research (Van de Woude, de Groot, & Janssen, 2006). The continuation of physical independence and optimal social functioning are key objectives in today's rehabilitation settings (Van de Woude et al., 2006). Focusing on research that furthers the field of disabled sports promotes this rehabilitation agenda by investing in technology and techniques to challenge and motivate athletes who have engaged in community based sports such as wheelchair basketball and rugby after their experience in structured rehabilitation settings.

Improving speed-related push technique research on a larger scale. This particular study focused on the athlete's speed-related push technique related to speed on one specific performance test. Similar studies have focused on various aspects of athletic push technique as well in an attempt to further this field of study (Cooper, 1990; De Groot et al., 2001; Goosey-Tolfrey & Moss, 2005). One such study researched which of the four commonly used push stroke patterns was most efficient in relation to energy cost and found that the choice of stroke pattern is dependent upon speed (De Groot, Veeger, Hollander, & Van Der Woude, 2004). This study suggested that a possible explanation to further investigate may not be on stroke pattern alone, but also may depend on propulsion technique elements, such as force application and timing (De Groot et al., 2004). Expansion of such biomechanics studies may further narrow the precise elements of push and propulsion technique for performance optimization.

Future studies should focus on the expansion of such validation research to include the remaining four elements of the *WSPT* as well. Reliability and validity of wheelchair performance tests have not been well established in previous literature, leaving questions as to performance testing changes over time (Barfield & Malone, 2012). Continued research to validate this and other tests should include methods which separate performance testing based on groups of sport specific classifications and disability levels. Evidence from previous anaerobic wheelchair ergometry tests has shown that variation in disability and subsequent trunk control influence power output (Bhambhani, 2002).

The most appropriate push techniques for optimal speed performance should be further examined to include these and any other potentially better markers of speed. While the results of this study did not show correlations between the push elements of push length, push frequency, peak force and speed performance when accounting for athlete's classification levels, this study indicated the need that exists in further examining these variables with the expansion of a larger study. In addition, it should be noted that there may be other speed related variables that exist beyond the scope of those tested in this research. The development of a speed improvement model for coaches and athletes to implement may be better formulated with further examination of the speed related variables researched in this and other studies.

Development of a speed-related wheelchair sports training protocol. The current study attempted to begin the process of developing an objective assessment of speed in a push technique protocol. Similar to Olympic competition, coaches and scientists are continually looking for optimal training methods for Paralympic sport (Barfield & Malone, 2012). While push frequency and speed was the only relationship found to be significantly correlated in this study ($r=.572, p=.026$), future research should examine push techniques that produce the best

performance results for athletes. Similar authors of wheelchair performance studies have examined the development of optimal push techniques. Chow et al. (2001) concluded that greater push time and push angle using a para-backhand push technique provided users the opportunity to transmit more force to the wheel, giving these users a faster overall movement speed. While this study discusses techniques for improved speed, other performance studies have focused on sports such as wheelchair cycling and racing, in which overall push economy is the focus (Goosey, Campbell, & Fowler, 2002). This Goosey, Campbell and Fowler (2002) study suggested that if athletes lowered their push frequency, their pushing economy would be improved. At this time, it is unclear which propulsion technique results in the best athletic performance. Expanded biomechanical and physiological research in this area may help to contribute to the formation of optimal wheelchair push performance techniques.

Speed assessment development. This particular study utilized two methods of coach ratings, a VAS Scale and a Likert-type ratings scale. For the purposes of this study, coaches' ratings were analyzed on the basis of the coach's interaction with his particular team and not the cumulative sample size of all four teams. The coaches' ability to rate only their particular team, within the particular sport of either wheelchair basketball or rugby, revealed through an examination of four scatter plots, that a mild to moderate positive relationship may exist between coaches ratings and measured speed. Scatter plots of the VAS scale for both basketball and rugby and measured speed indicated the VAS scale may be more closely related to actual measured speed than Likert-type ratings. The Likert scale- type of coach ratings indicated that coach ratings of speed on the basketball teams seem to be more highly associated with measured speed in m/s than the rugby coach ratings as the Likert-type scale of rugby coach ratings and speed did not indicate an associated relationship. The VAS analysis indicated that the basketball coaches'

ratings of speed and the rugby coaches' ratings of speed appeared to result in a similar relationship.

The researcher of this study indicated that future research should continue to develop formal speed assessments to help coaches gather objective speed assessment data to assist in formulating expanded use of speed assessment techniques. It should be noted that the assessment protocol tested in this study may or may not have translated to game speed since the assessment protocol included a measurement device and a standard wheelchair that are not included in a practical game and practice situations. Future research may investigate the continued development of objective speed-related skills assessments to assist in developing speed-related training techniques. Even at the most elite Paralympic level, coaches have mostly completed coaching education programs that were designed almost exclusively for able-bodied athletes (Cregan, Bloom, & Reid, 2007). With regard to speed assessment development, objective training techniques may enhance the skills coaches already possess through experience, education programs and other coaching influences. At this time, it is unclear what the best technique is for coaches to formally and properly assess their player's performance speed.

Similarly, across all sports, coaches must succeed at identifying essential performance components of elite sports in order to best recruit and train prospective athletes (Barfield & Malone, 2012). Further work through expanding performance studies is necessary to help gain insight into push mechanics in order to assist coaches with training designs and protocols for improved sports performance (Goosey-Tolfrey & Moss, 2005). Future speed development training protocols may help coaches to monitor the progress of athletes and may help show the effectiveness of training (De Groot et al., 2004). Many coaches are typically interested in attaining maximum speed performance from their athletes in the shortest possible time using a

minimum number of strokes (Cooper, 1990). Valid and reliable performance tests may allow coaches to assess a player's standard of performance and individualize instruction and practice (De Groot et al., 2004). The expanded efforts of further validity and reliability research of performance tests, taking into account the aforementioned studies, may help coaches and players meet their speed performance goals.

Demographic factors that were collected as potential relational factors with speed only indicated correlations between years of experience playing the athlete's particular sport and measured speed. No significant correlations were found in examining the relationship between years of experience prior to the onset of a disability and measured speed. This may serve as an important indication for future research as it may show that anyone has the potential of developing skills as an athlete to play wheelchair sports after the onset of a disability without having prior years of experience. This should be further investigated to confirm this assertion.

Conclusion

The research findings of this study had several practical implications, which may be beneficial as a starting point for future expanded research studies. After partialing out the effect of disability, relationships between the propulsion elements of push length and peak force were not correlated with speed performance. Push frequency and speed however, were shown to be moderately correlated ($r=.57$). Additionally, the demographic qualities of years of sport-specific experience and age were suggested as potential influences on speed performance as well. Continued research within larger scale wheelchair performance based studies could yield more powerful findings, leading to improved wheelchair mobility techniques among athlete populations. The growth of a database of knowledge could emerge from such studies, leading to

a more evidence-based approach to improving performance factors and the understanding of wheelchair sports as well as the effects of long-term wheelchair use (Van der Woude, 2001).

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APPENDIX A

WHEELCHAIR SPORTS PERFORMANCE TEST PROTOCOL

20M Sprint Capacity Test

I. Test Component(s):

Sprint Capacity Test-the Sprint Capacity test is a wheelchair push test to evaluate an athlete's speed and push efficiency at full speed.

With the SmartWheel®, data is collected for each athlete to determine the following:

- a. *Peak Push Force*-For each steady-state push (all pushes in the session except for the first three), the peak force is measured. This is average peak force of all the steady-state pushes and represents the total force applied.
- b. *Speed/Push-Frequency Ratio [m]*-This ratio is the average steady-state speed divided by the average steady-state push frequency. It provides an indication of how many pushes per second are being used to achieve the average speed.
- c. *Push Length*-the average length of the athlete's push, in degrees.
- d. *Peak Average Force Ratio*-the ratio between the peak force during a push, and the average force during a push. It is averaged across all steady-state pushes. It provides an indication of how smoothly pushes are applied to the SmartWheel's® handrim. A lower ratio indicates the peak force is more close to the average force, which can indicate a smoother push.
- e. *Speed*-This is the average speed of the SmartWheel® during steady state (the time after the first 3 pushes of start-up).
- f. *Time* – the total elapsed time of the test.

II. Rationale:

Speed is a critical aspect to an athlete's performance on the court. This measure provides the athlete and coach data related to an athlete's speed and push efficiency. These test components provide data indicative of an athlete's ability to breakaway to score, accelerate to defend an opposing athlete, or beat an opponent to a particular spot on the court. Other components through SmartWheel® data provide data that indicates how smooth a push is (to minimize the number of pushes required to achieve optimal speed), push efficiency (energy conservation), and how much force it requires to reach an optimal steady speed.

III. Measurement Protocol:

See figure 1 for court set-up. The protocol for this specific test is adapted from the field performance tests suggested by Brasile (1986, 1990) and Vanlandewijck et al. (1995). The player takes a position behind the baseline. Following the signal of measurement staff, the athlete has to cover the 20m distance as quickly as possible. Each athlete may have two attempts within the two-minute period. The best result is recorded.

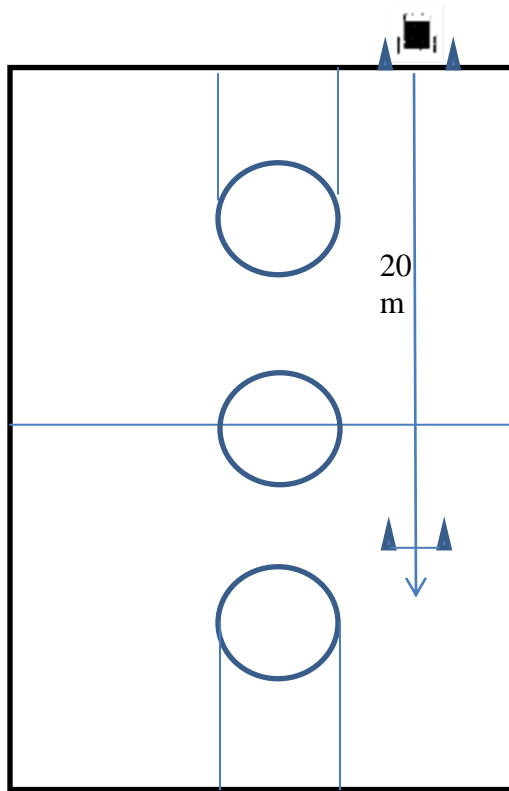


Figure 1: Court Set-up for Sprint Capacity Test

IV. Adaptations:

The SmartWheel® is the optimal method to collect the most comprehensive data for speed performance. However, a timed 20m test to provide a baseline speed might be considered to assess speed as measured in time with a stopwatch. Vanlandewijck et al. (1995) utilized a torque sensor, mounted on the drive axle, to measure the torque (i.e., push force) generated at both handrims.

APPENDIX B

UNIVERSITY AND MEDICAL CENTER INSTITUTIONAL REVIEW BOARD

APPROVAL LETTER



EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
1L-09 Brody Medical Sciences Building · Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · www.ecu.edu/irb

Notification of Initial Approval: Expedited

From: Social/Behavioral IRB
To: [Christina Brown-Bochicchio](#)
CC: [David Loy](#)
Date: 5/2/2012
[UMCIRB 11-000974](#)
Re: Wheelchair Sports Performance Test: A SmartWheel® Technology Field Validation Pilot Study

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 5/2/2012 to 5/1/2013. The research study is eligible for review under expedited category #4, 7. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

The approval includes the following items:

Name	Description
Informed Consent Form Final Version.doc History	Consent Forms
Player/Coach Demographic form History	Surveys and Questionnaires
Sprint Capacity Coach Rating Form V1.doc History	Surveys and Questionnaires
Wheelchair Sports Performance Test History	Standardized/Non-Standardized Instruments/Measures

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418 IRB00004973
East Carolina U IRB #4 (Behavioral/SS Summer) IORG0000418

Study.PI Name:
Study.Co-Investigators:

APPENDIX C

SMARTWHEEL® REPORT PARAMETER DEFINITIONS

Client & Session Information

Name	The Subject's Name
Age [y]	The Subject's Age
Gender	The Subject's Gender
Weight [kg]	The Subject's Weight (not including the wheelchair)
Height [cm]	The Subject's Height
Primary Diagnosis	The Subject's Primary Diagnosis
Additional Information	Any other information that's relevant to know about the subject
Date & Time	The date and time of the Smartwheel session.
Notes	Any notes specific to the particular SmartWheel® Session

General Session Results

Activity	The activity that was performed. Often, this will be a set clinical protocol, such as Tile-Protocol
Time [s]	The total elapsed time of the session
Distance [m]	The total distance traveled by the Smartwheel during the session.
Average Speed [m/s]	The average speed of the Smartwheel over the entire session
Highest Speed [m/s]	The highest speed achieved by the Smartwheel over the entire session
Number of Pushes	The number of complete pushes detected by the Smartwheel over the entire session

Session Results- Steady State

These parameters are averages calculated from all pushes except for the first 3.

Peak Force [N]	For each steady-state push, the peak force is measured. This is average peak force of all the steady-state pushes.
Peak Backwards Force [N]	For each steady-state push, the peak backwards force is measured. This is average peak backwards force of all the steady-state pushes. This shows the extent to which the client is effectively braking the wheelchair with every push. This parameter is only valid in this sense if the subject is not actually trying to brake.
Speed [m/s]	This is the average speed of the Smartwheel during steady state
Off-Rim Acceleration [m/s/s]	This is the acceleration (measured as negative) experienced by the Smartwheel when the subject is not actively pushing. This parameter should only be used when the subject is on a level surface, goes in a straight line and pushes are symmetrical.
Speed/Push Frequency Ration [m]	This ratio is the average steady-state speed divided by the average steady-state push frequency. It provides an indication of how many pushes per second are being used to achieve the average speed.
Push Length [deg]	This is the average length of the subject's push in degrees.
Push Frequency [1/s]	This is how many times per second, on average, the subject pushes on the Smartwheel.
Peak/Average Force Ratio	This is the ratio between the peak force during a push, and the average force during a push. It is averaged across all steady-state pushes. It provides an indication of how smoothly pushes are applied to the Smartwheel handrim. A lower ratio indicates the peak force is more close to the average force, which can indicate a smoother push.
Average Push Force [N]	This is the average force the subject applies to the Smartwheel handrim, averaged over all steady-state pushes.
Push Mechanical Effectiveness [%]	This indicates the approximate percentage of applied force which is directed such that the Smartwheel is accelerated. For example, if much of the applied force is down or outward, this value will be lower, because pushing inwards toward the hub, or pushing outward do not actually make the Wheelchair accelerate. This parameter is only intended to provide a red flag

	for abnormally insufficient pushing.
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Session Results-Startup

These parameters are averages calculated from all pushes except for the first 3

Peak Force Push 1[N]	This is the peak force the subject applied to the Smartwheel handrim during the first push. (note: this force is the total force applied)
Peak Force Push 2[N]	This is the peak force the subject applied to the Smartwheel handrim during the second push. (note: this force is the total force applied)
Peak Force Push 3[N]	This is the peak force the subject applied to the Smartwheel handrim during the third push. (note: this force is the total force applied)
Distance after 2nd push [m]	This is the distance covered by the Smartwheel during the first two pushes.
Distance after 3rd push [m]	This is the distance covered by the Smartwheel during the first three pushes.
Speed after 2nd push [m/s]	This is the speed that was achieved after the 2 nd push.

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ATTACHMENT D

20M SPRINT CAPACITY TEST: COACHES RATING EVALUATION OF
PLAYER SPEED

20M Sprint Capacity Test: Coaches Rating Evaluation of Player's Speed

Player name: _____

Player Functional Level of Injury: _____

Please rate the speed of the player listed above:

1	2	3	4	5	6	7
Very Slow			Moderately Fast			Very Fast

20M Sprint Capacity Test: Coaches Rating Evaluation of Player's Speed Visual Analog Scale

Please mark along the continuum the speed of the player listed at the top of this form:

Extremely Slow		Extremely Fast

APPENDIX E

WHEELCHAIR SPORTS PERFORMANCE TEST DEMOGRAPHIC QUESTIONNAIRE

DATE
RECEIVED:

WHEELCHAIR SPORTS PERFORMANCE TEST DEMOGRAPHIC QUESTIONNAIRE

Player Number or Coach Name:	Date
Are you a player on this team or a coach: <input type="checkbox"/> Player <input type="checkbox"/> Coach	

QUESTIONS FOR COACHES ONLY:

How long have you coached this particular team? Please check the box indicating the number of years:	<input type="checkbox"/> less than 1 year <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9 <input type="checkbox"/> 10 <input type="checkbox"/> more than 10 years		
In general, how long have you coached athletic teams?	<input type="checkbox"/> 5 or more years	<input type="checkbox"/> 1 to 5 years	<input type="checkbox"/> Less than 1 year

QUESTIONS FOR PLAYERS ONLY:

What sport do you play on this team: What is your current classification level for the sport you play on this team:	<input type="checkbox"/> Wheelchair basketball <input type="checkbox"/> Quad rugby <input type="checkbox"/> .5 <input type="checkbox"/> 1.0 <input type="checkbox"/> 1.5 <input type="checkbox"/> 2.0 <input type="checkbox"/> 2.5 <input type="checkbox"/> 3.0 <input type="checkbox"/> 3.5 <input type="checkbox"/> 4.0 <input type="checkbox"/> 4.5
How many years of previous athletic experience did you have prior to the onset of your disability?	<input type="checkbox"/> less than 1 year <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9 <input type="checkbox"/> 10 <input type="checkbox"/> more than 10 years
How many years of experience have you had playing this particular sport after the onset of your disability?	<input type="checkbox"/> less than 1 year <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9 <input type="checkbox"/> 10 <input type="checkbox"/> more than 10 years
How many hours per week do you practice this particular sport during the sport season?	<input type="checkbox"/> less than 1 hour <input type="checkbox"/> 1 <input type="checkbox"/> 3 <input type="checkbox"/> 5 <input type="checkbox"/> 7 <input type="checkbox"/> 9 <input type="checkbox"/> 11 <input type="checkbox"/> 13 <input type="checkbox"/> more than 13 hours
Current Age: _____	

ATTACHMENT F

PLAYER AND COACH INFORMED CONSENT FORM



Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Wheelchair Sports Performance Test: A SmartWheel® Technology Field Validation Pilot Study

Principal Investigator: Christina Brown-Bochicchio

Institution/Department or Division: Department of Recreation and Leisure Studies

Address: 300 Curry Court, 1413 Belk Building, Mail Stop 540, Greenville, NC 27858

Telephone #: (252) 328-4640

Researchers at East Carolina University (ECU) study problems in society, health problems, environmental problems, behavior problems and the human condition. Our goal is to try to find ways to improve the lives of you and others. To do this, we need the help of volunteers who are willing to take part in research.

Why is this research being done?

The purpose of this research is to...test the reliability and validity of the Wheelchair Sports Performance Test. The decision to take part in this research is yours to make. By doing this research, we hope to learn if this Wheelchair Sports Performance Test is a valid and reliable measure of performance for disabled athletes with the future intent of the test's use as a training tool for coaches and players.

Why am I being invited to take part in this research?

You are being invited to take part in this research because you are a member of an organized sports team and you use a manual wheelchair for mobility. If you volunteer to take part in this research, you will be one of about 20 people to do so.

Are there reasons I should not take part in this research?

I understand that I should not participate if I feel unsafe in the wheelchair, which will be used to test for my speed performance.

What other choices do I have if I do not take part in this research?

You can choose not to participate.

Where is the research going to take place and how long will it last?

The research procedures will be conducted at Barwell Road Community Center. You will need to come to 3935 Barwell Road, Raleigh, NC 27610, 1 time during the study. The total amount of time you will be asked to volunteer for this study is 1 hour over the next 2 months.

What will I be asked to do?

You are being asked to do the following: Arrive at Barwell Road Community Center at the determined time and date for one testing session. A simple form will need to be filled out to collect some demographic data to input into the SmartWheel® computer program. The SmartWheel® will then be

fitted on the wheelchair. You will then be asked to perform a series of five short performance tests to collect data regarding your manual wheelchair push performance.

What possible harms or discomforts might I experience if I take part in the research?

It has been determined that the risks associated with this research are no more than what you would experience in everyday life.

What are the possible benefits I may experience from taking part in this research?

We do not know if you will get any benefits by taking part in this study. This research might help us learn more about your athletic performance as it pertains to the push of your wheelchair. Hopefully, this data will help you with future training before, during and after your competitive sports season. However, there may also be no personal benefit from your participation but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?

Unfortunately, you will not be paid for taking part in this research.

What will it cost me to take part in this research?

It will not cost you any money to be part of the research. The sponsor of this research will pay the costs of: Testing procedures and any subsequent fees related to processing the collected data.

Who will know that I took part in this research and learn personal information about me?

To do this research, ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- Any agency of the federal, state, or local government that regulates human research.
- The University & Medical Center Institutional Review Board (UMCIRB) and its staff, who have responsibility for overseeing your welfare during this research, and other ECU staff who oversee this research.
- People designated by PCMH and University Health System;
- Additionally, the following people and/or organizations may be given access to your personal health information and they are: Your team coach and researchers conducting this study.

How will you keep the information you collect about me secure? How long will you keep it?

The information collected in this study will be stored on a password-protected laptop, which has the sole purpose of being utilized to collect data in conjunction with the SmartWheel®. Your collected data will be kept for three years. Your information will be used only for the purposes of this study and will not be distributed for any other commercial, non-commercial or related use. Upon the event that your information will be used for future research, your personal information will be stripped of any identifiers and may be used without anyone knowing that it is information from you, the participant.

What if I decide I do not want to continue in this research?

If you decide you no longer want to be in this research after it has already started, you may stop at any time. You will not be penalized or criticized for stopping. You will not lose any benefits that you should normally receive.

Who should I contact if I have questions?

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at (949) 370-9981 (days, between 10:00am-5:00pm EST).

If you have questions about your rights as someone taking part in research, you may call the Office for Human Research Integrity (OHRI) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director of the OHRI, at 252-744-1971

I have decided I want to take part in this research. What should I do now?

The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

Participant's Name (PRINT)**Signature****Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

Person Obtaining Consent (PRINT)**Signature****Date**

APPENDIX G

SCATTERPLOTS OF THE RELATIONSHIP BETWEEN MEASURED SPEED
DURING THE *20M SPRINT CAPACITY TEST* AND COACH RATING SCALES

Figure G1

Relationship between wheelchair basketball speed (m/s) and VAS scale.

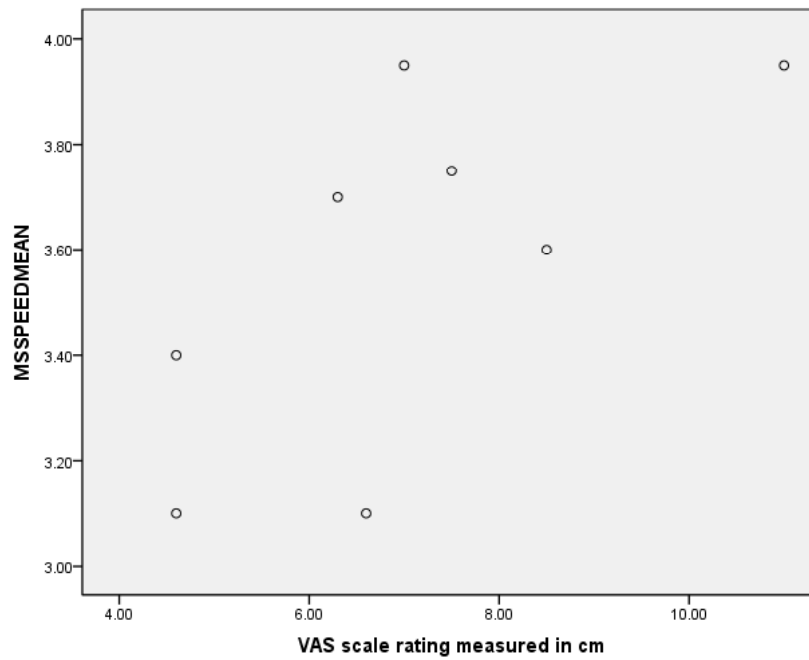


Figure G2

Relationship between wheelchair basketball speed (m/s) and Likert-type scale.

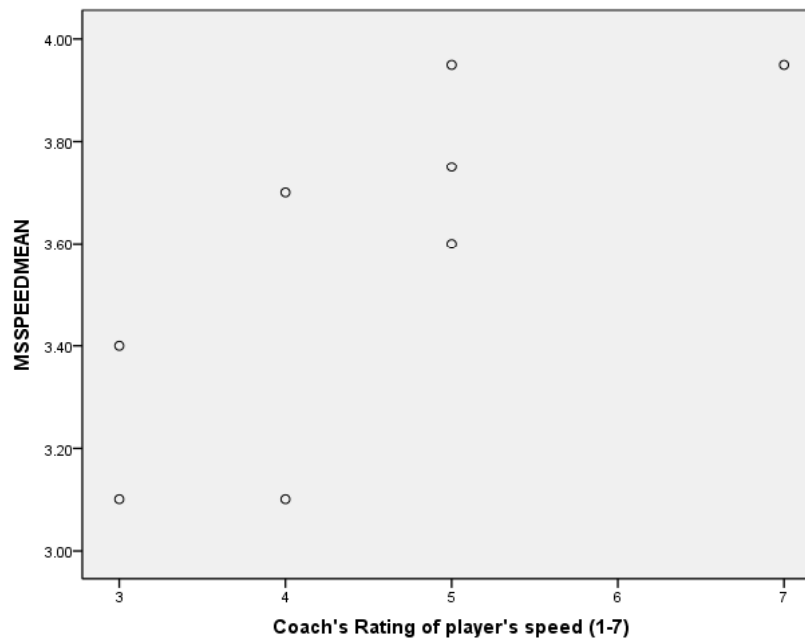


Figure G3

Relationship between wheelchair rugby speed (m/s) and VAS scale.

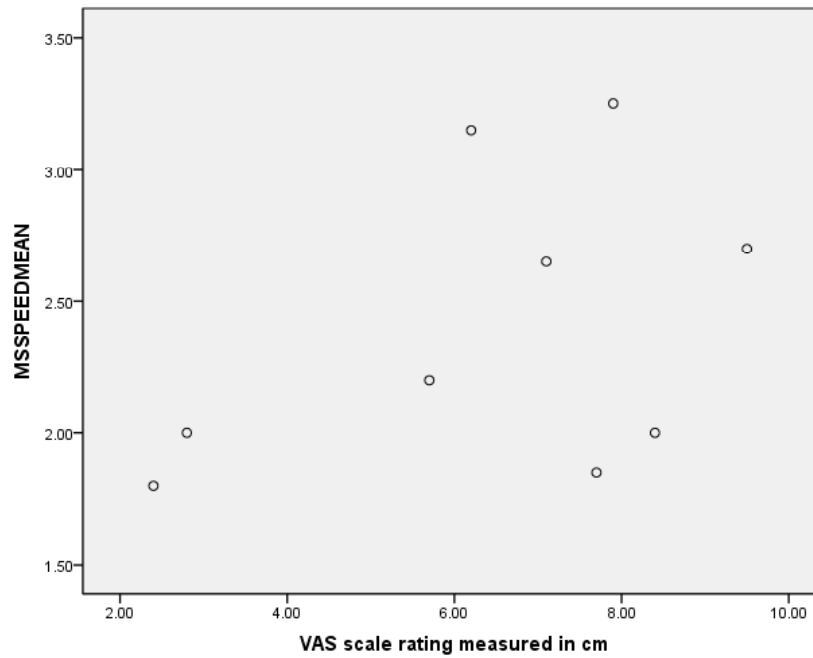


Figure G4

Relationship between wheelchair rugby speed (m/s) and Likert scale.

